Laser Safety Audits – in Laboratory Facilities

David H. Sliney, Ph.D.

US Army Center for Health Promotion and Preventive Medicine

Aberdeen Proving Ground, MD 21010 USA

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ANSI Z136.1-2000, paras. 1,4,5 Role of the LSO

- ANSI Z136.1-2000—LSO performs audits
- But what is an audit?
- How often?
- Class 3b and Class 4 lasers

Where are the lasers in NASA?

- *Some Interesting History*
  - Laser Audits—(Laser Hazard Surveys) were conducted by the US Army Environmental Hygiene Agency (the fore-runner of USACHPPM) in 1966-1970s
- Most lasers were in laboratories (Z136.1)
- Some used in diagnostics for wind tunnels
- Some outside for atmospheric research and satellite tracking (ANSI Z136.6)

Laser Safety Audits --the Objectives

- To identify unsafe work practices
- Inventory potentially hazardous operations
- One-on-one training
- The bottom line: *to prevent accidents*

…so, Where Do Accidental Laser/Optical Radiation Injuries Occur?

- Injuries from lamps and arcs are rare
  - principally from cumulative UV exposures from arc lamps—but requires minutes
  - Laser Hazards
  - Potential for serious injury
  - Low probability for exposure
  - Retinal injuries from short-pulse laser exposures when eye protectors ignored

What Measurements Are Needed?

- What measurements—what instruments?
- Laser beams pose a different risk probability than..
  - Ionizing radiation sources
  - Sources of airborne contaminants
- Most laser beams are above the MPE
- *So, when, where and why to measure?*

Laboratory Accidents

- Most eye injuries have occurred in research and engineering laboratories. Why?
- Open beams
  - During alignment
  - For flexibility in calibration procedures
  - Experimental changes in setup
- “I know where the beam is!” (Famous last words)

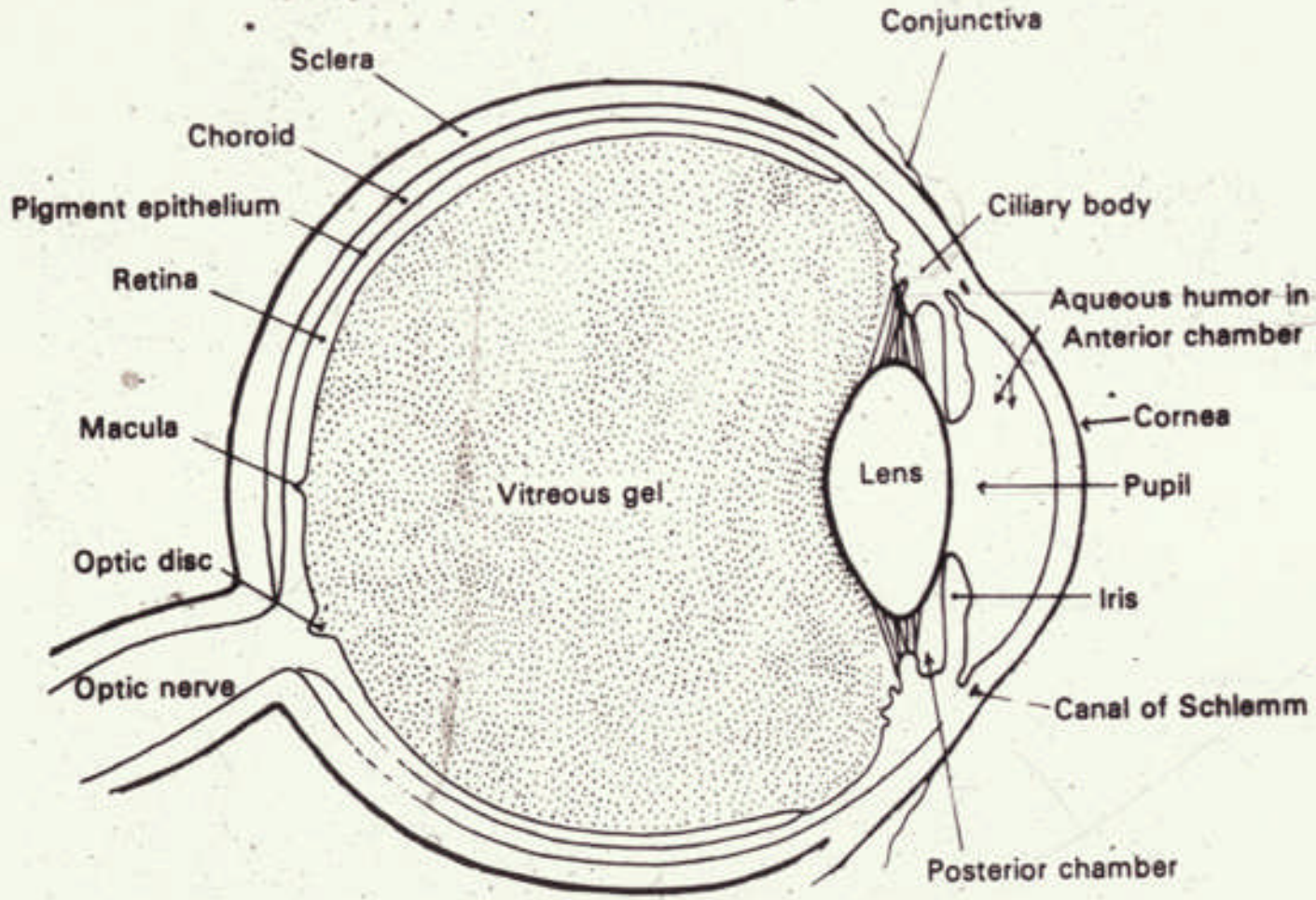
Those Ocular Injuries in the Laboratory

- Common elements:
  - Small, upward beam from Brewster-angle window or beam deflector
  - Q-switched or mode-locked ultra-short pulse
  - Small energy in beam (microjoules)
  - Victim fails to wear eye protection

Laser Hazards - Risk Assessment

- The risks to the eye and skin of industrial and research staff from laser use generally result from open beam paths
- Ocular hazards are most significant
- Risks are greatest from reflected beams and for procedures without a fixed beam
- A collimated beam may pose a hazard over some distance.

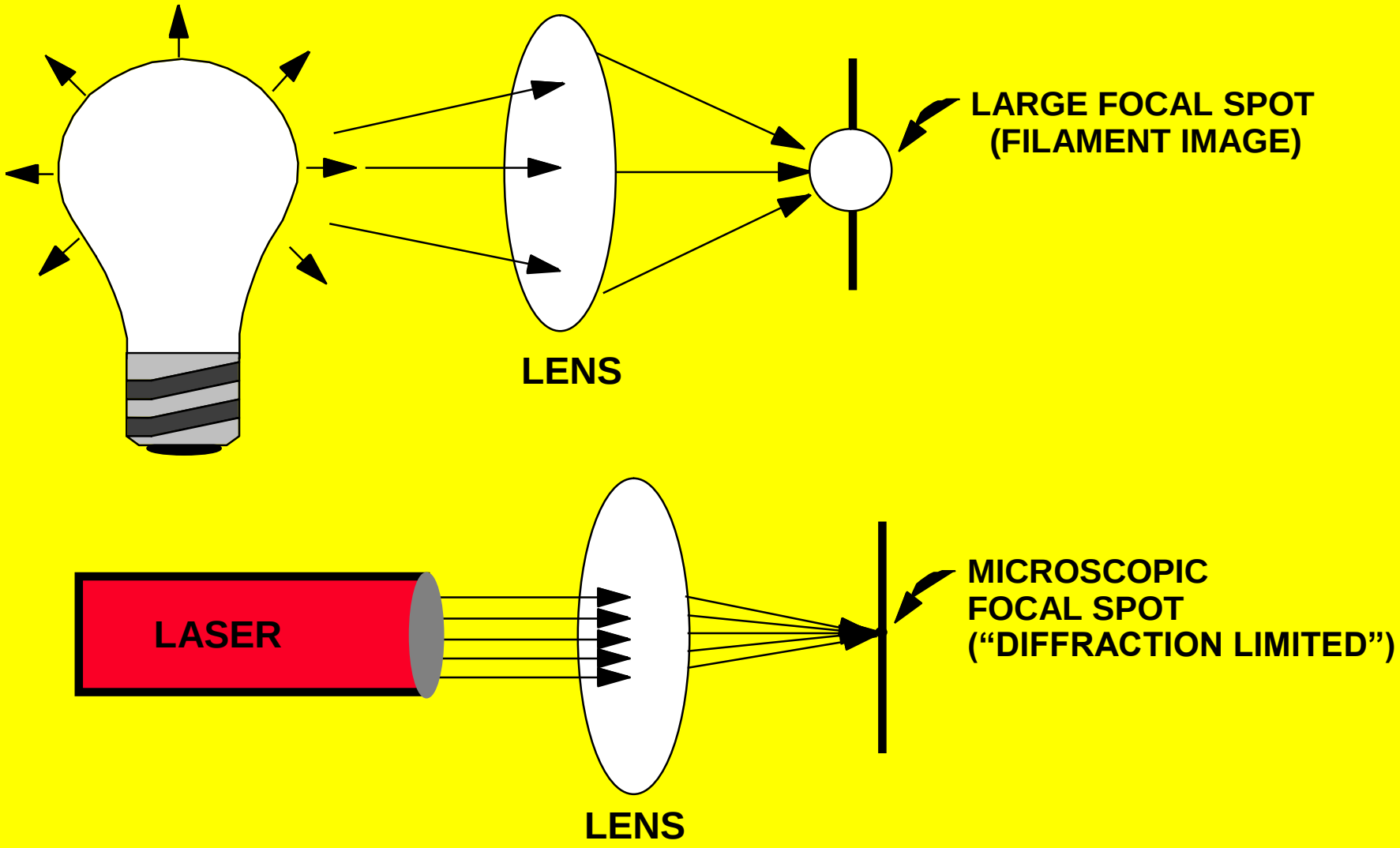
The Human Eye ~25 mm diameter



The eye's 2- to 7-mm pupil is a "small target"

Why is a laser so hazardous?

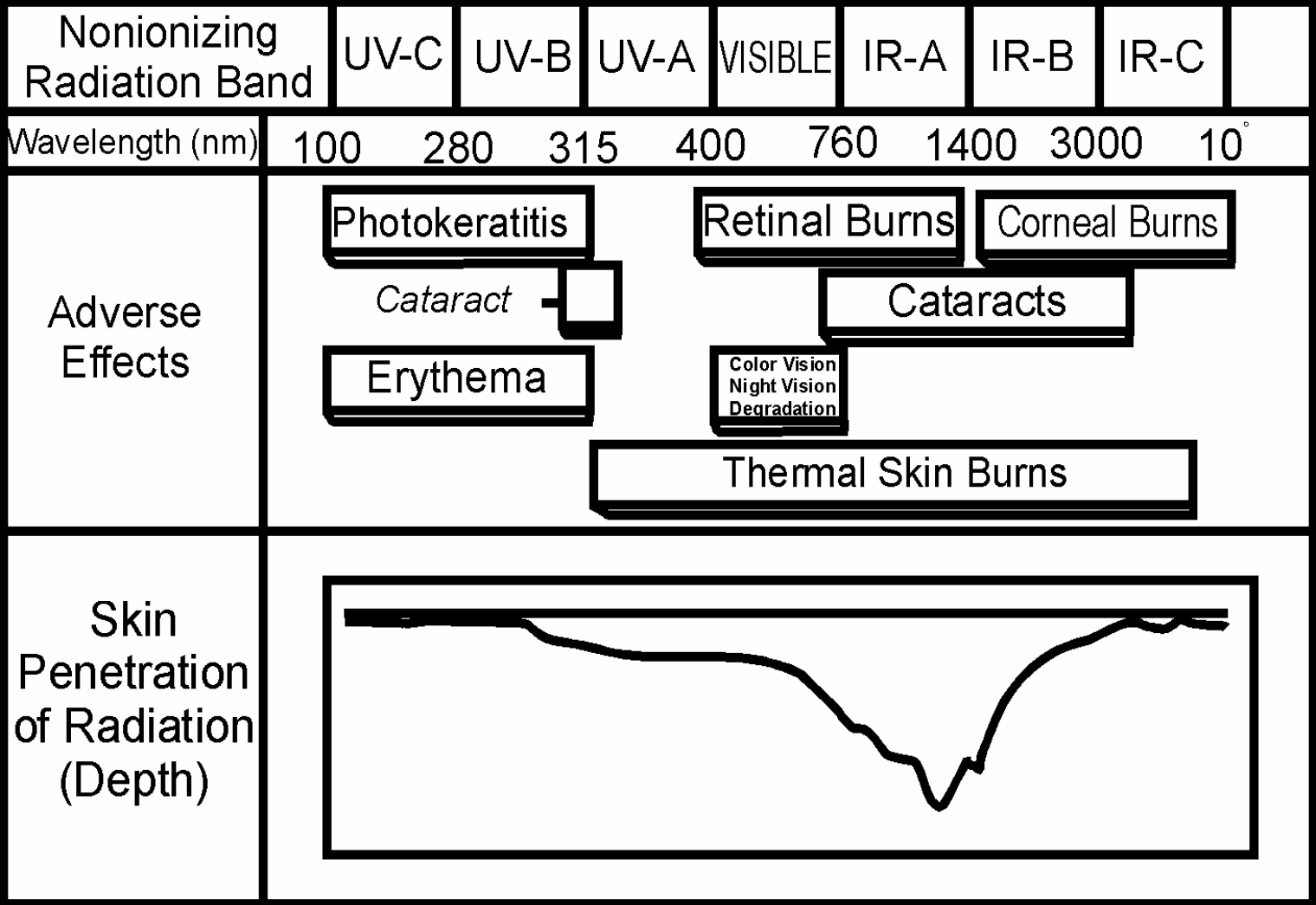
- From optical physics, the answer is: “radiance”
  - …but what is that?
- Radiance is the physical quantity we know as “brightness”
- Even a 1-mW laser pointer is 10X brighter than the surface of the sun!
- It can therefore be focussed to an exquisitely small spot (as for surgery)…or within the eye!



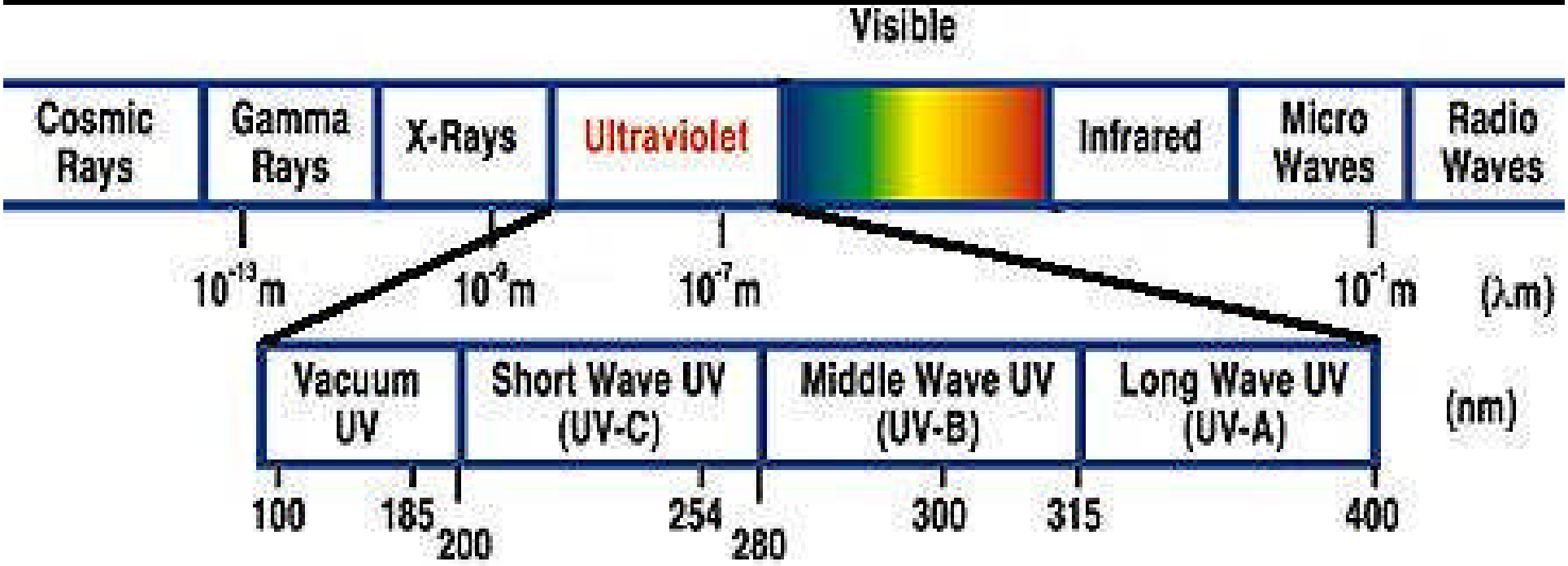
From Sliney DH and Trokel, S, 1993

The CIE Photobiological Spectral Bands

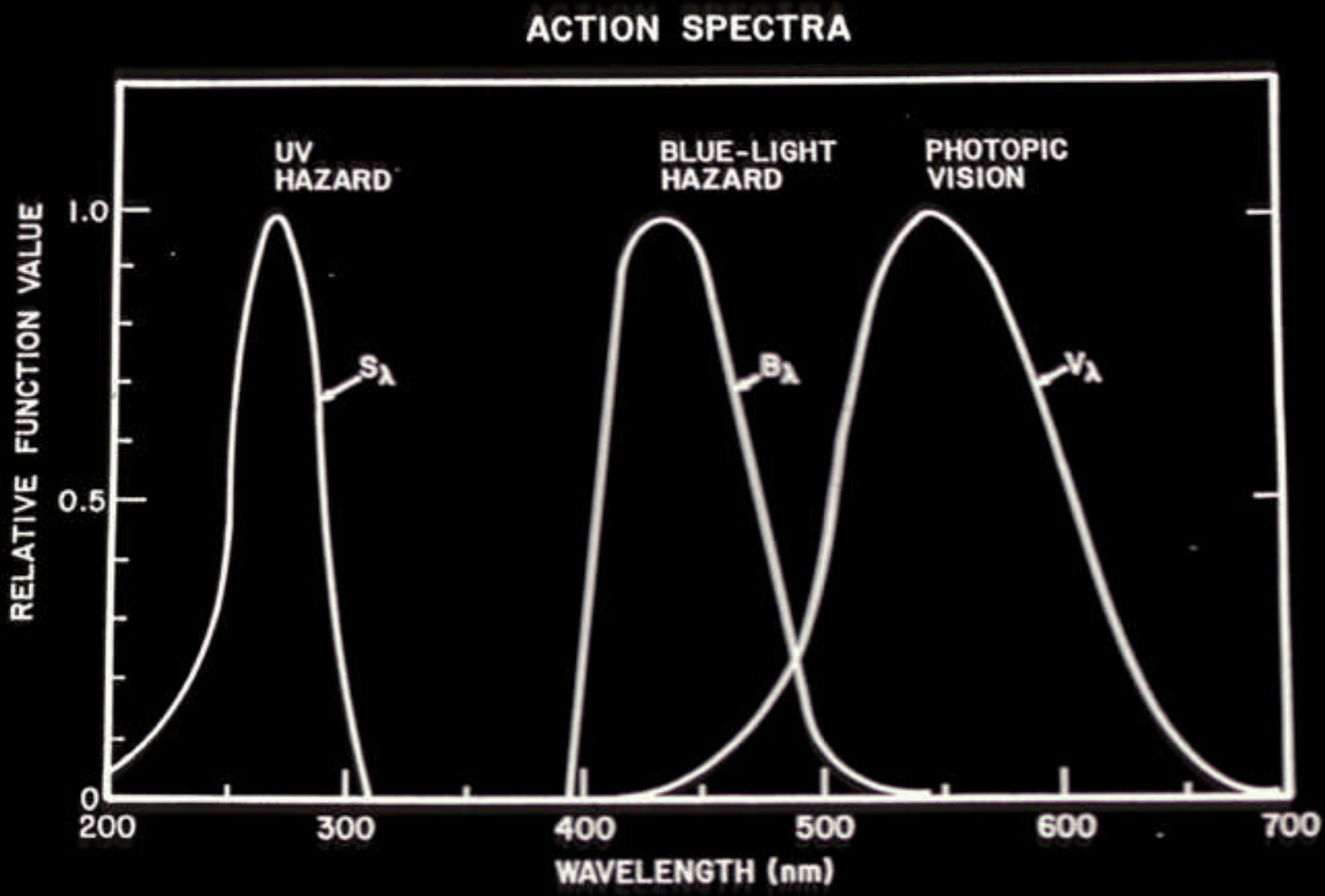
Photobiological Effects



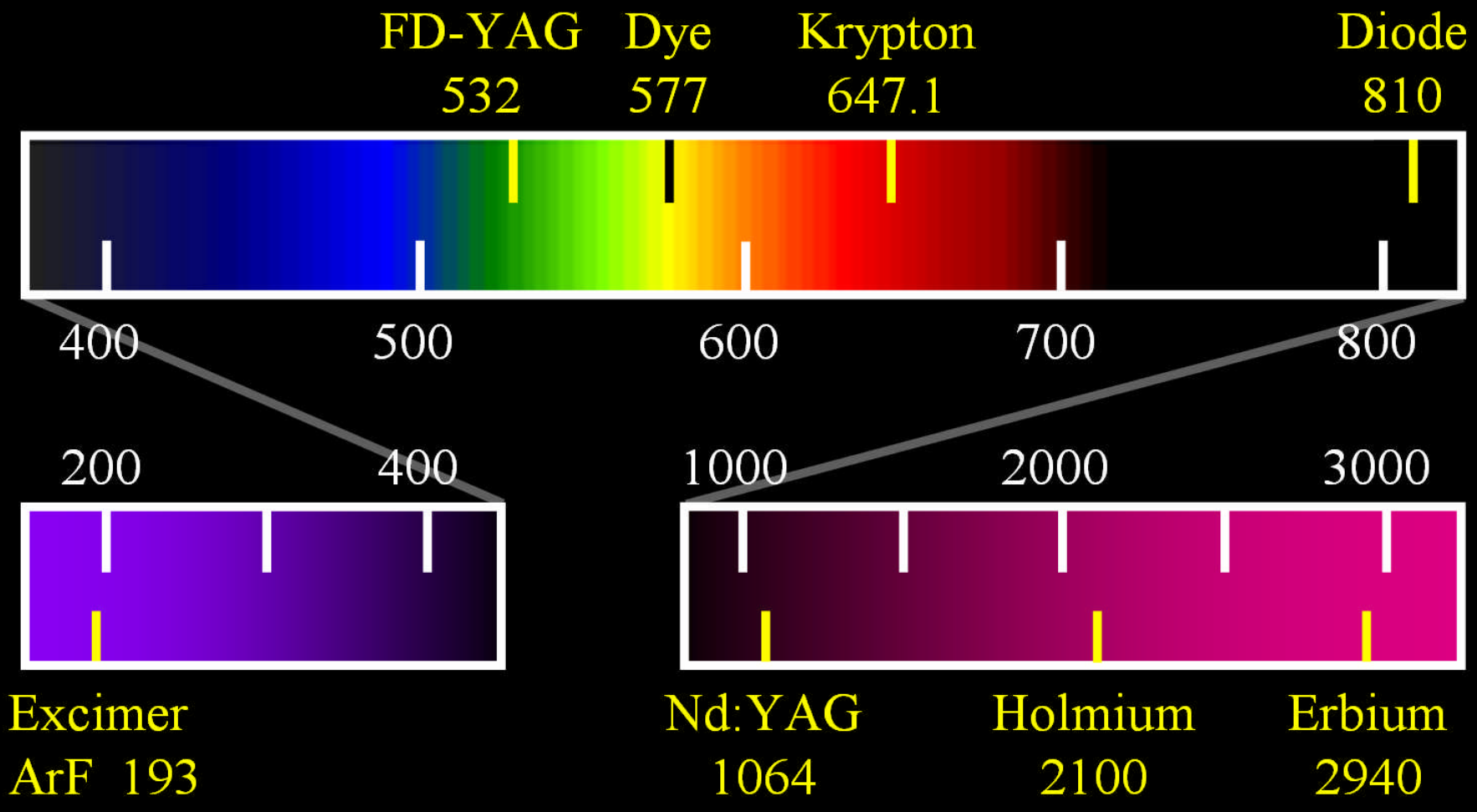
The ultraviolet-visible spectrum are of primary concern for cumulative effects…



Photochemical Damage Mechanisms

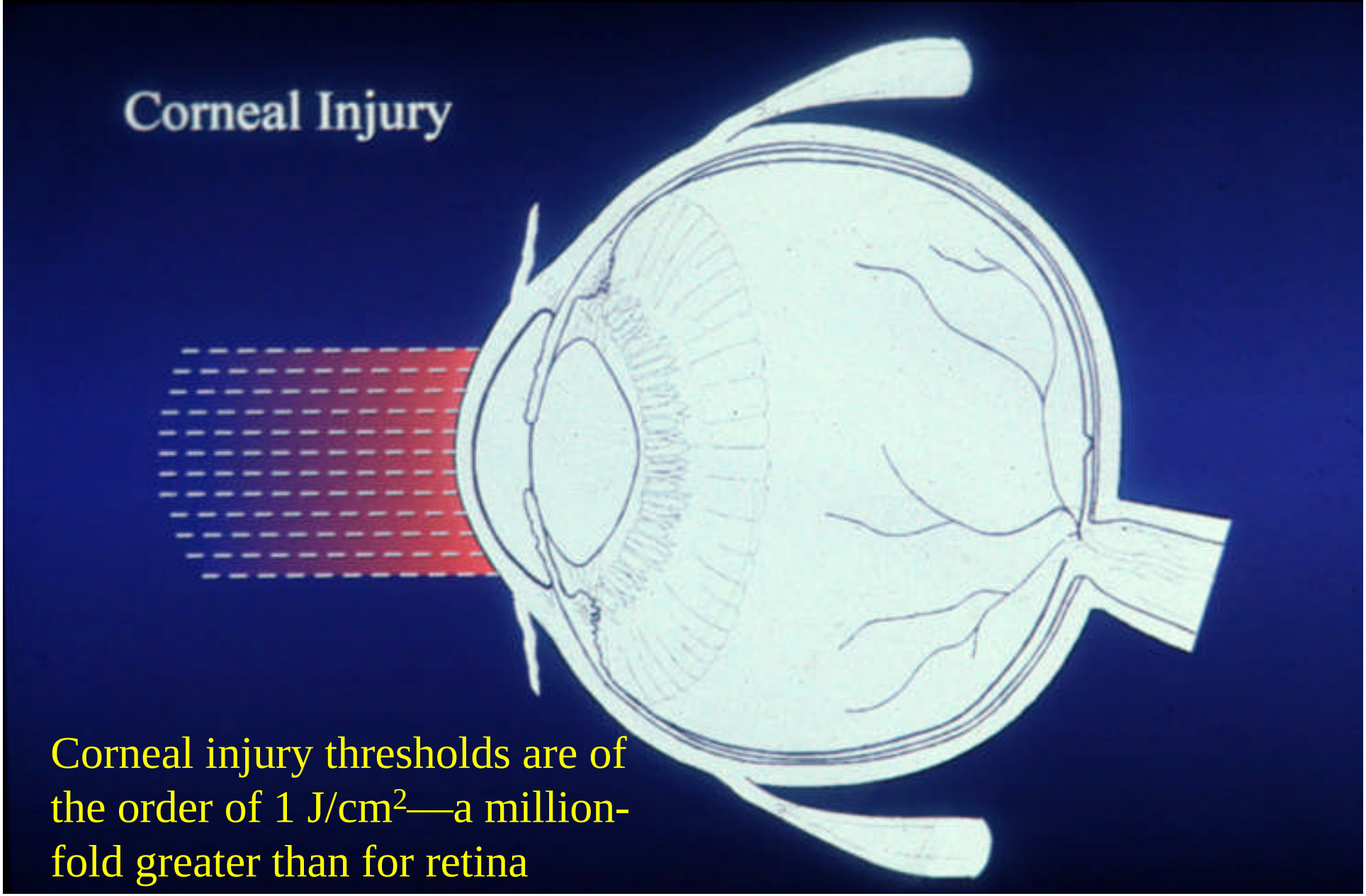


Some Common Laser Wavelengths—Ultraviolet to Infrared IR-B



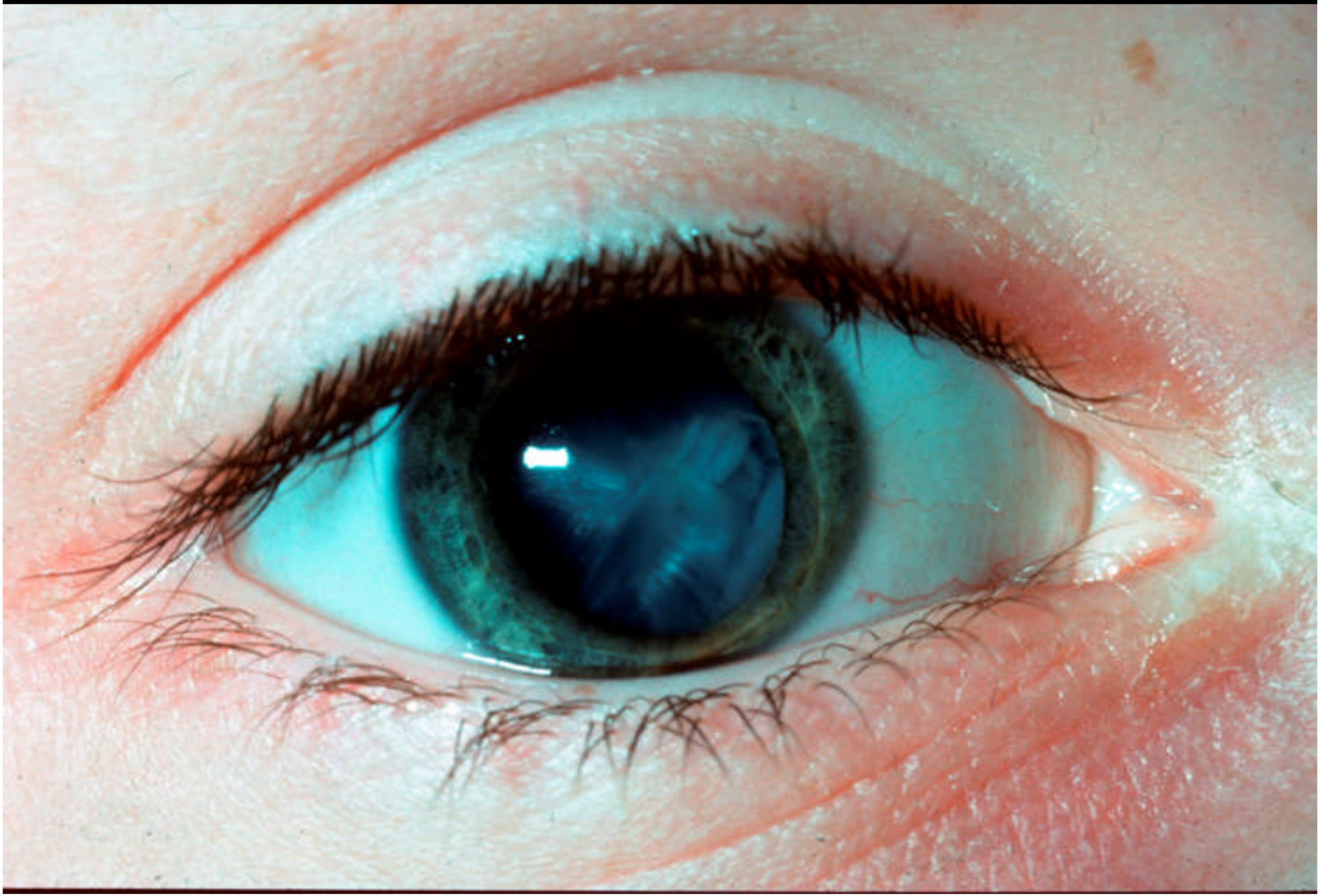
M A Mainster 93

Corneal Hazards: UV-B/C, IR-B, IR-C

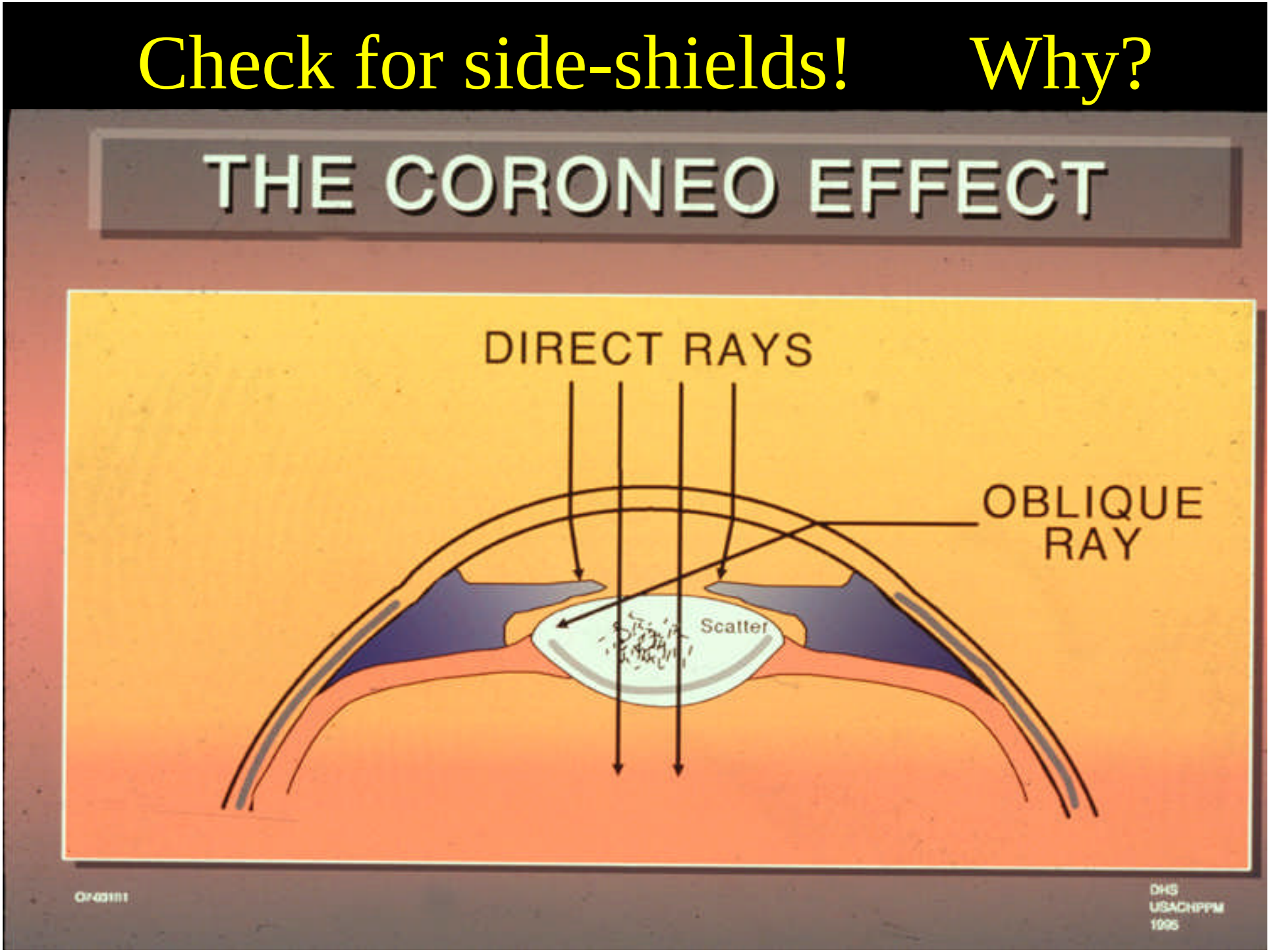


Corneal injury thresholds are of the order of 1 J/cm^2—a million-fold greater than for retina

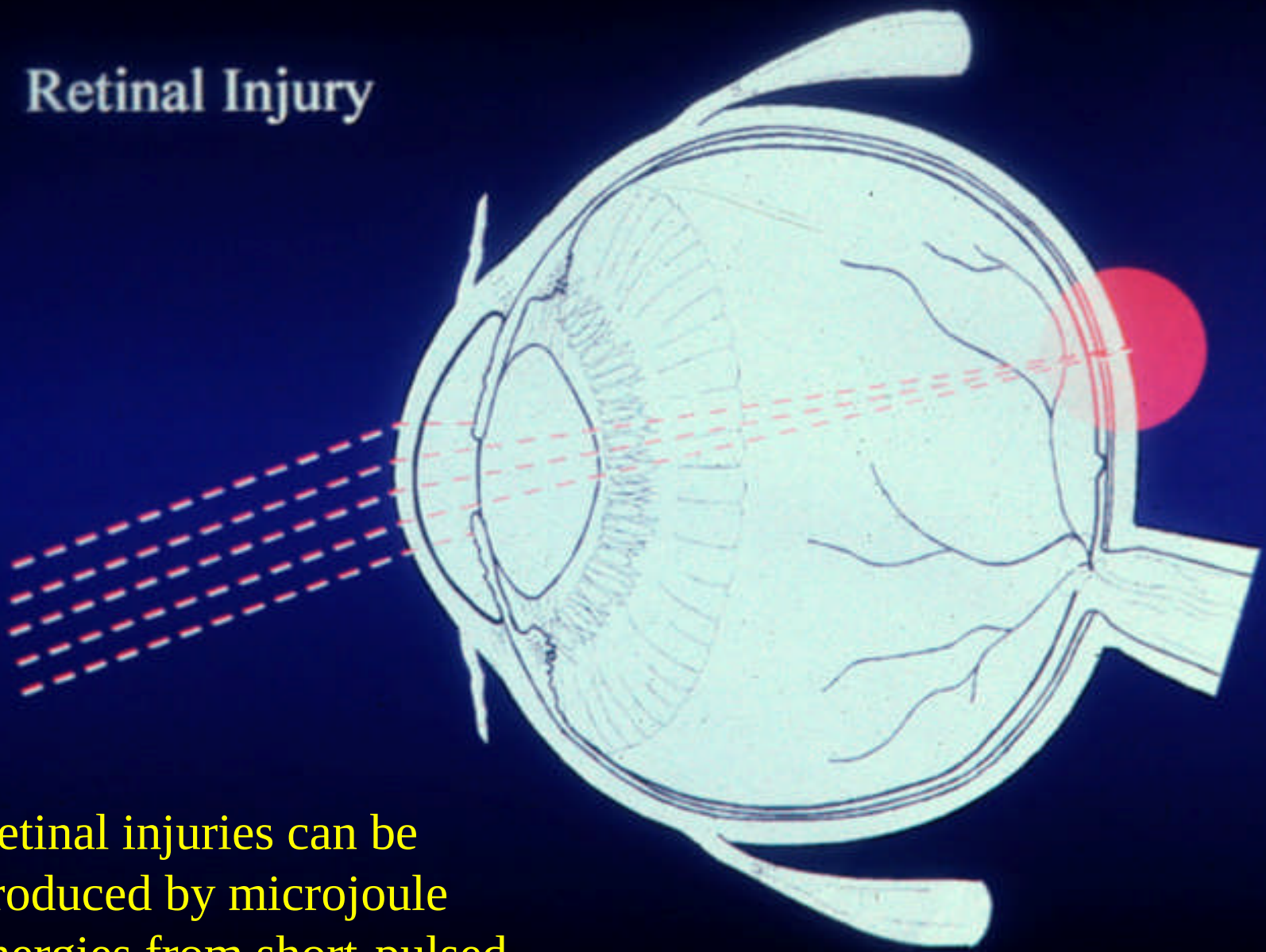
Cataract - More than 1 million cases in the USA / year



Check for side-shields! Why?

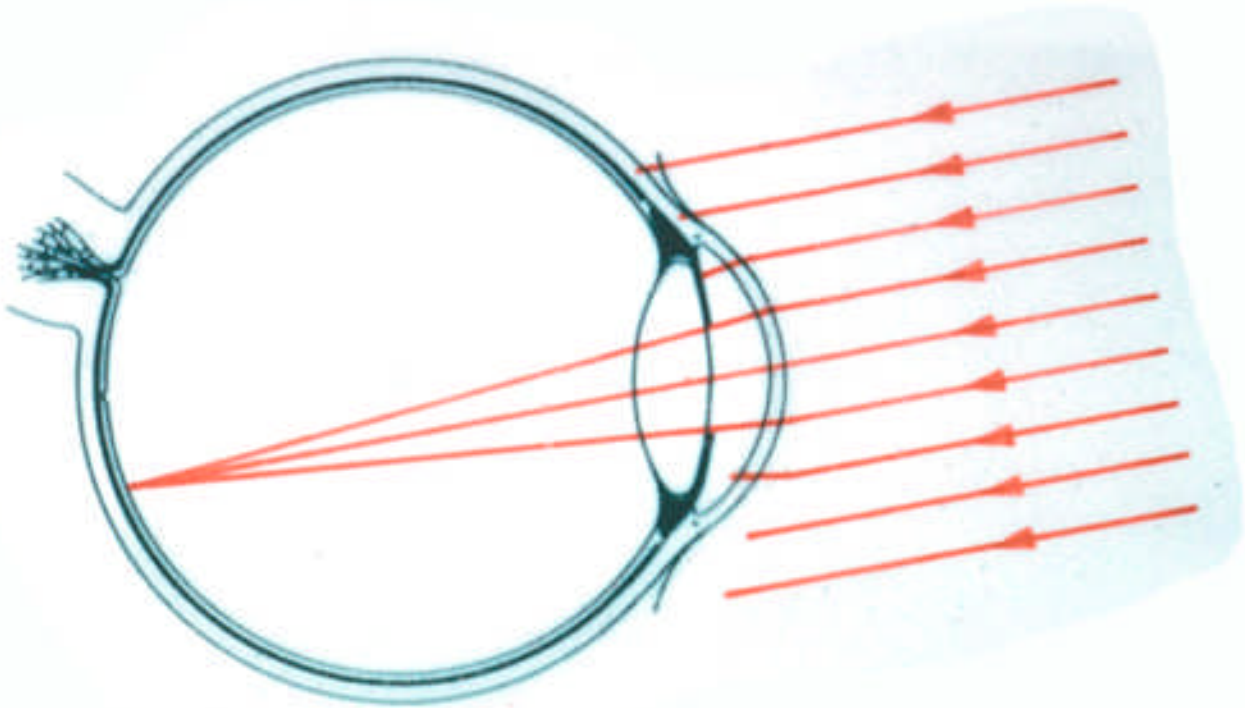


Retinal Injury



Retinal injuries can be produced by microjoule energies from short-pulsed lasers—hence the concern

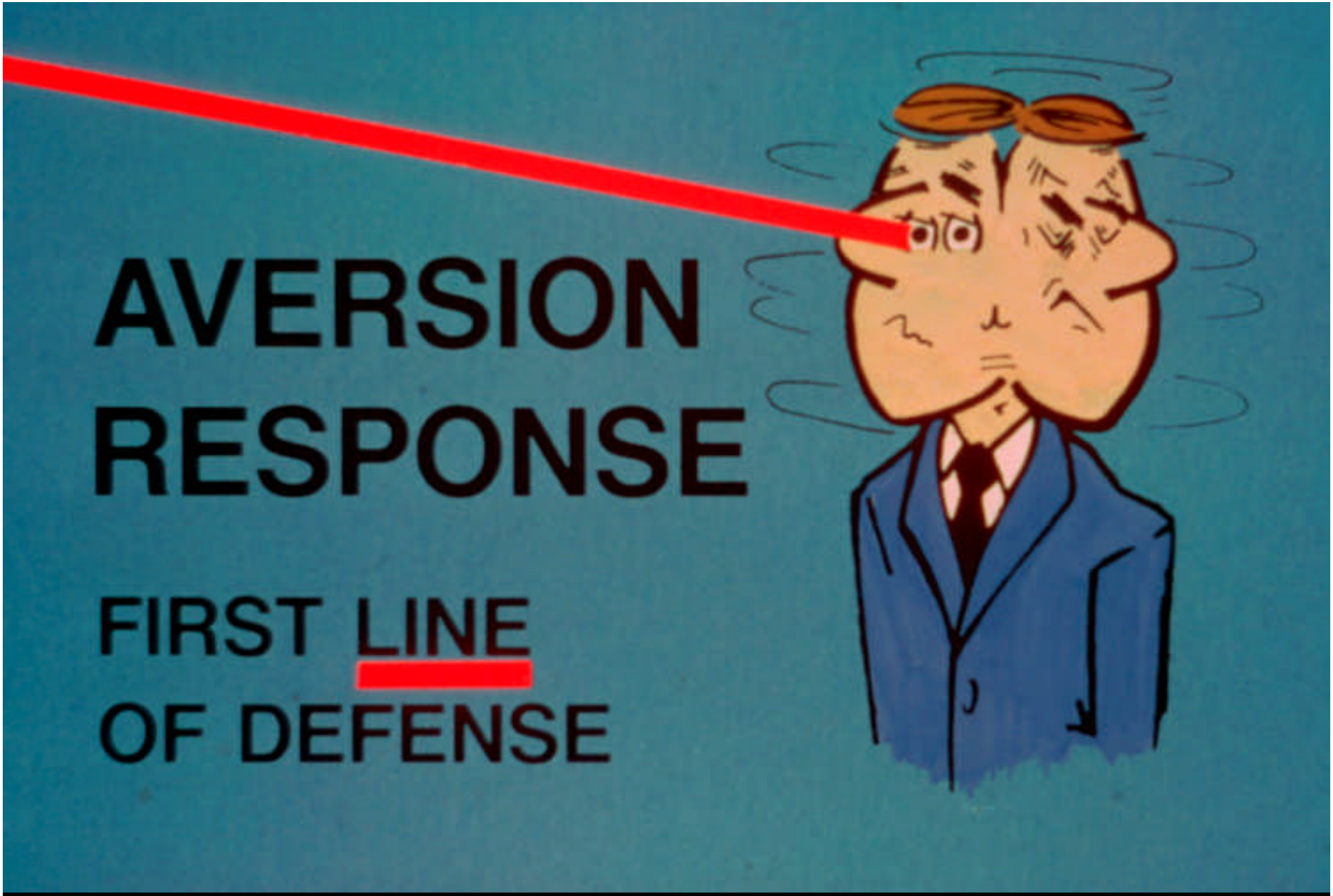
Off-Axis Retinal Exposure



Eye: Fovea

- An even smaller region within the Macula.
- From this small region, all detailed vision takes place.
- A laser produced lesion on this area would be catastrophic.

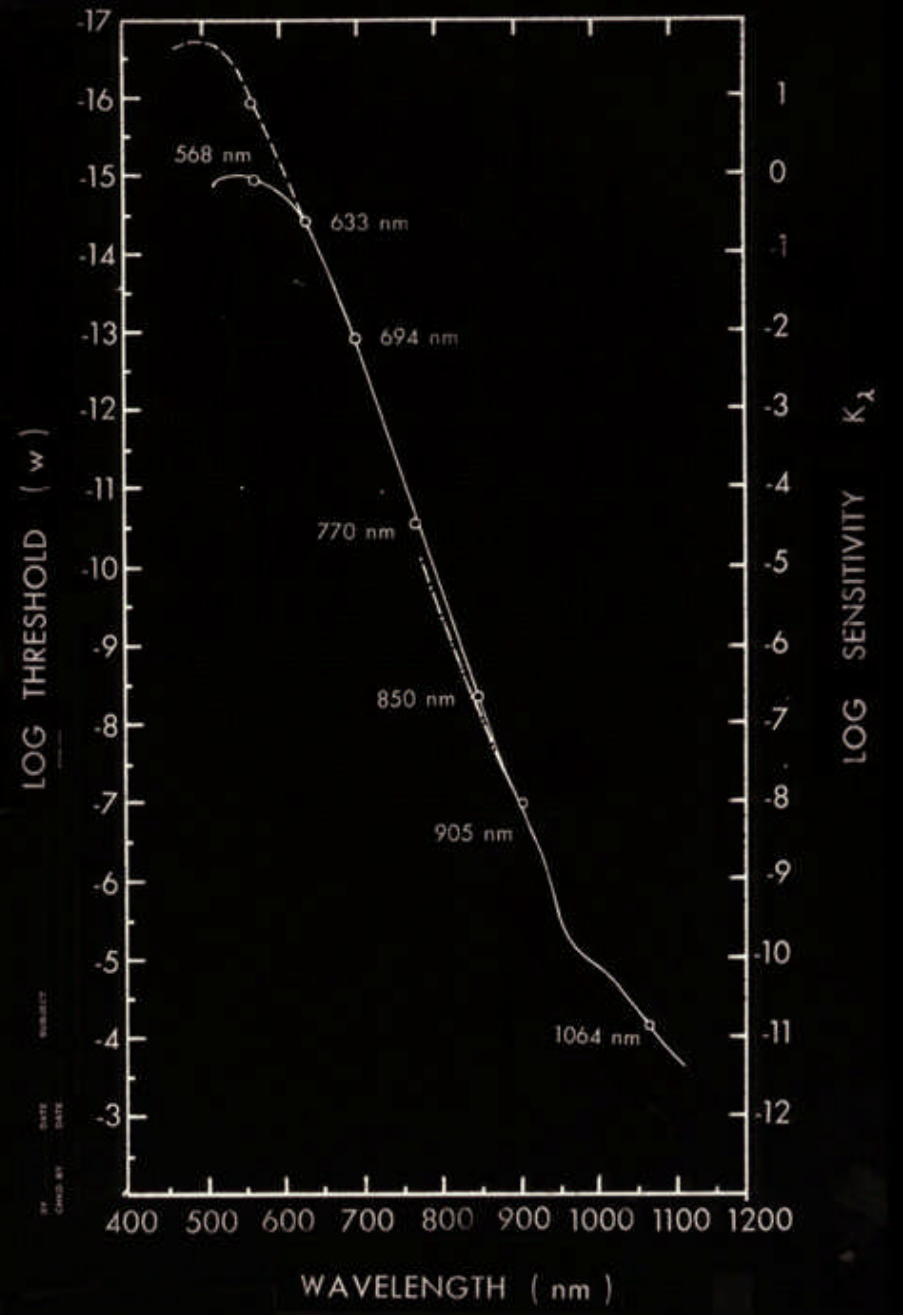
Even a laser pointer is ten times brighter than the sun itself



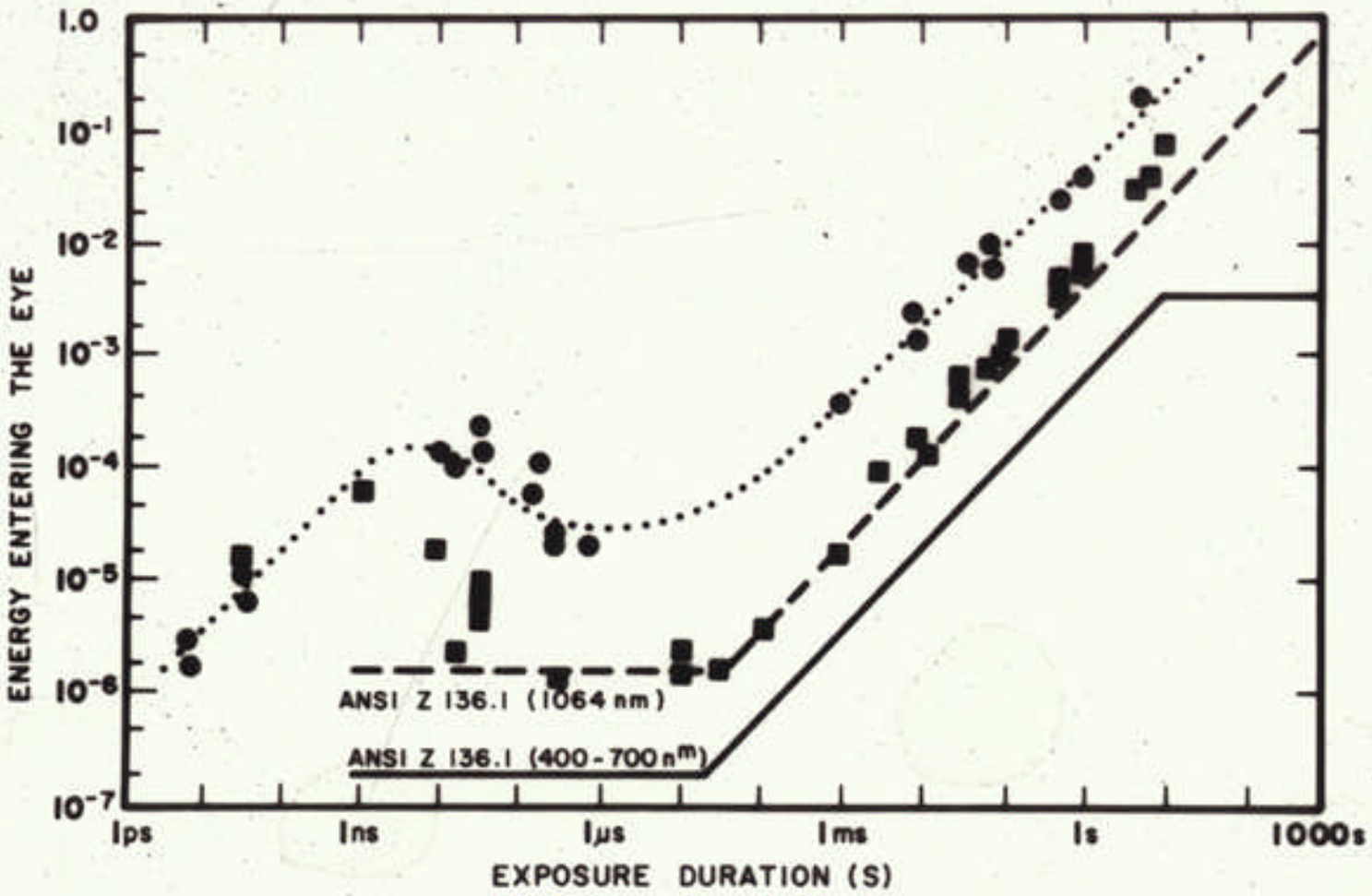
Eye movement, head movement, blink, lid-closer—
standardized as 0.25 s

Spectral Response of Daylight Vision

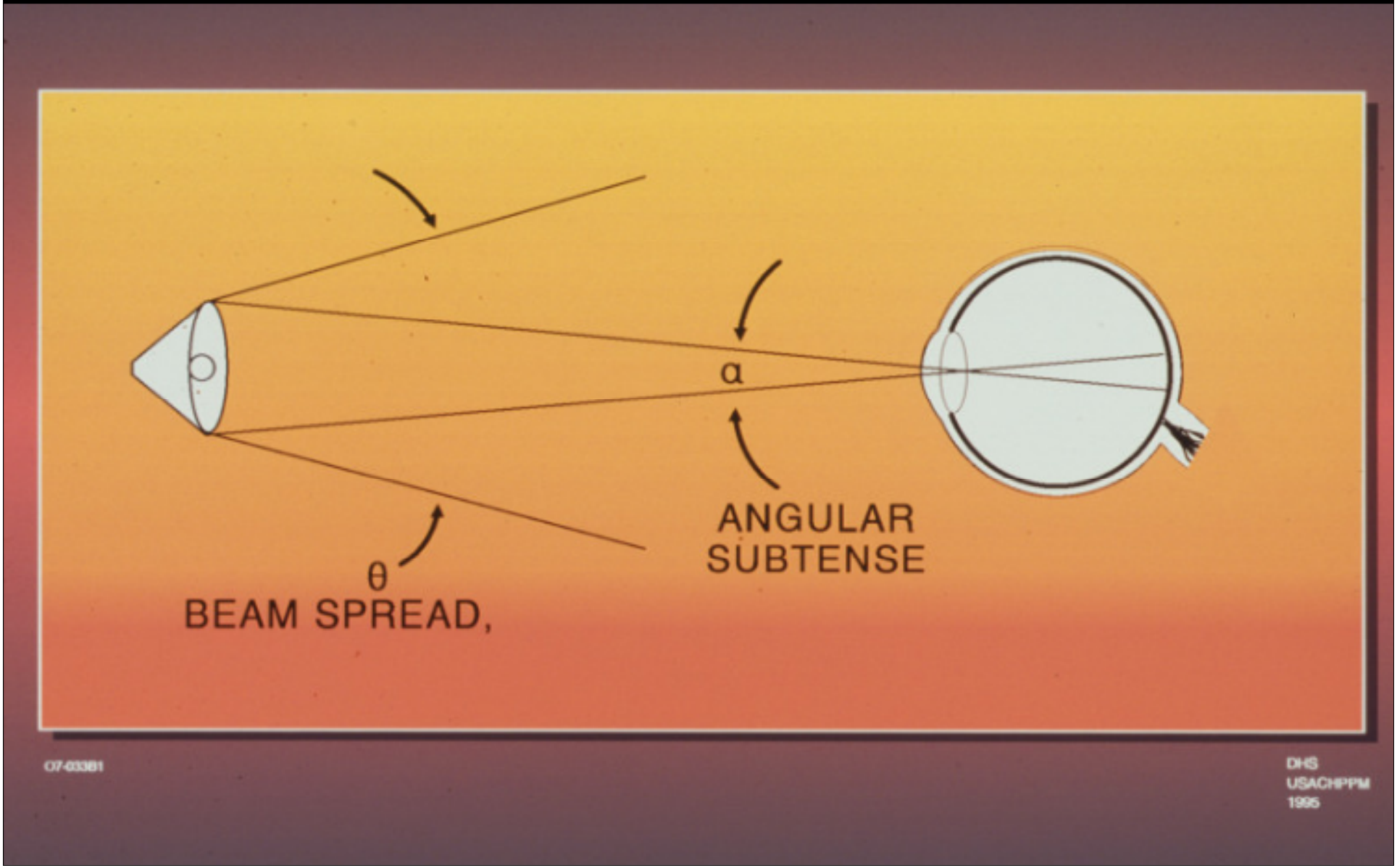
- Logarithmic plot shows spectral dependences of photopic (cone) threshold over 14 orders of magnitude
- Even the 1064-nm Nd:YAG laser wavelength can be seen—but at levels close to the exposure limit



Retinal Injury Thresholds as Energy



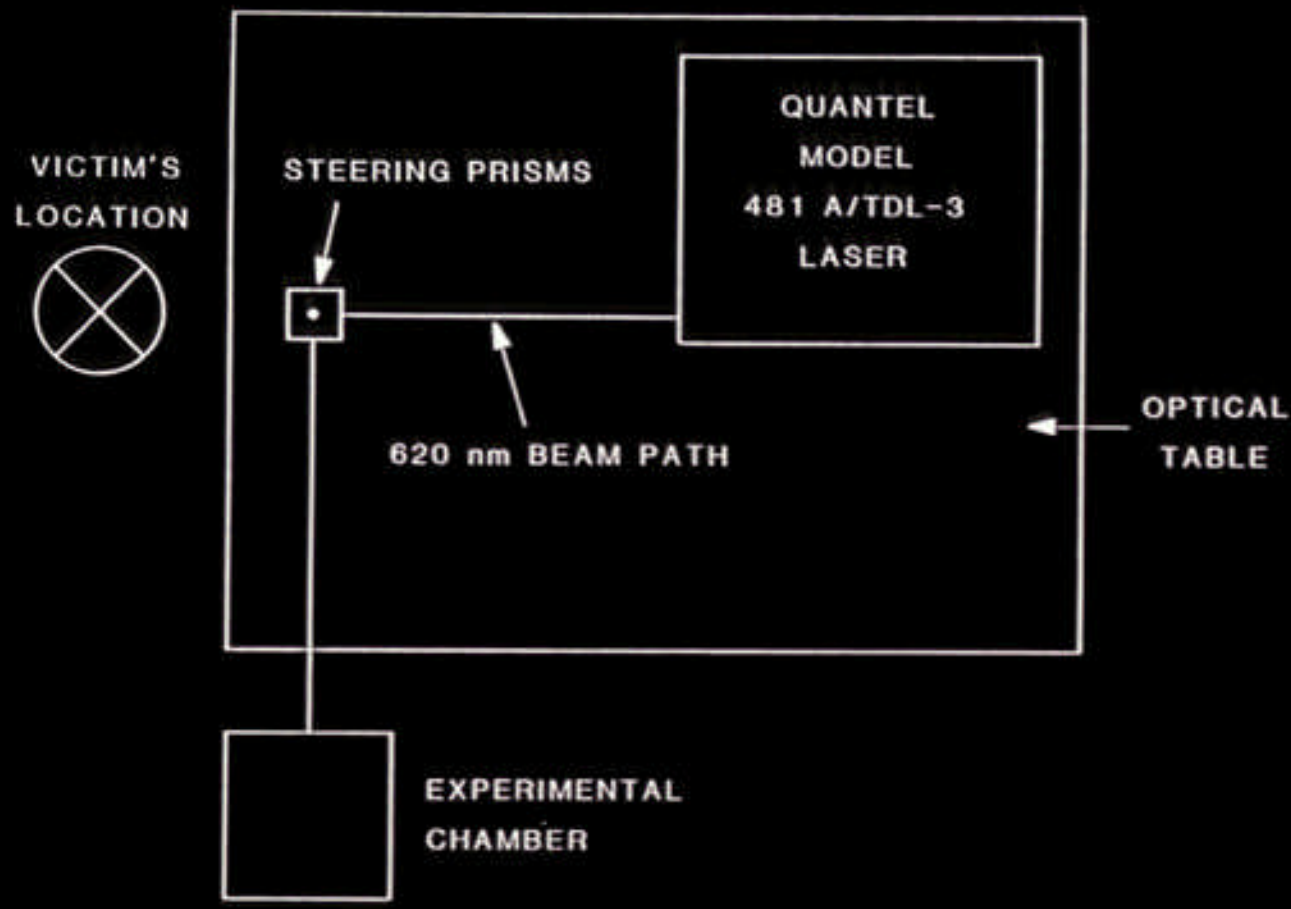
Angular subtense and beam spread are different



LASER INDUCED EYE INJURIES

LABORATORY ACCIDENT

- Physicist working with Nd:YAG Q-switched laser fails to wear eye protector, because he "knew beam location."
- With laser housing removed, a small 1-mJ beam was reflected upward from a Brewster-Angle Window.
- He sensed a popping sound, then sensed blood flow in the vitreous. Thence, serious visual loss.
- After four months, a paracentral scotoma remained.
- Source: David Decker, Laser Focus, August 1977.



SCHEMATIC OVERVIEW SHOWING BEAM PATHS AND THE VICTIM'S LOCATION. AT THE STEERING PRISM THE BEAM COMES UP OUT OF THE ILLUSTRATION, THEN PARALLEL TO THE OPTICAL TABLE INTO THE EXPERIMENTAL CHAMBER.

Laser Safety Standards

Two types of standards

- Manufacturer standards – *regulates emission*
  - *Example:* FDA/CDRH *Federal Laser Performance Standard*
  - *International:* IEC 60825-1.2-2001
- User Safety Standards – *regulates exposure*
  - *Example: ANSI Z136.1-2000 Safe Use of Lasers*
- Both use the same hazard (risk) classification scheme: Classes 1 through 4

In an audit…

- Organize the audit based upon laser hazard classification
- The big advantage: manufacturer's classification is the major step in hazard evaluation
- Look for the manufacturer's label!

Be familiar with laser classes--examples

CLASS 1: Nonhazardous Lasers or Enclosed Lasers

REQUIREMENTS

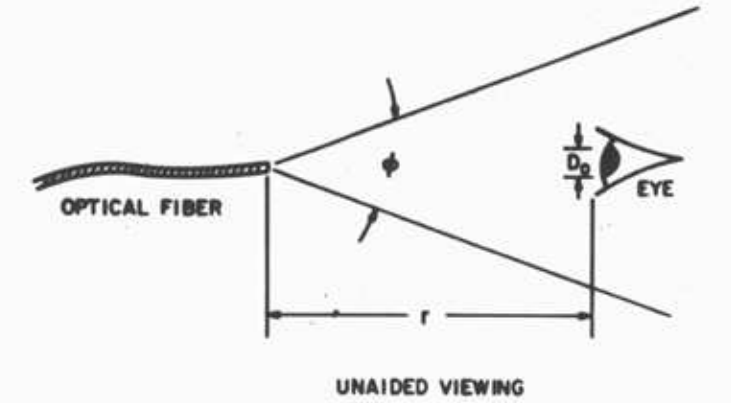
Labeling

Interlocks on case

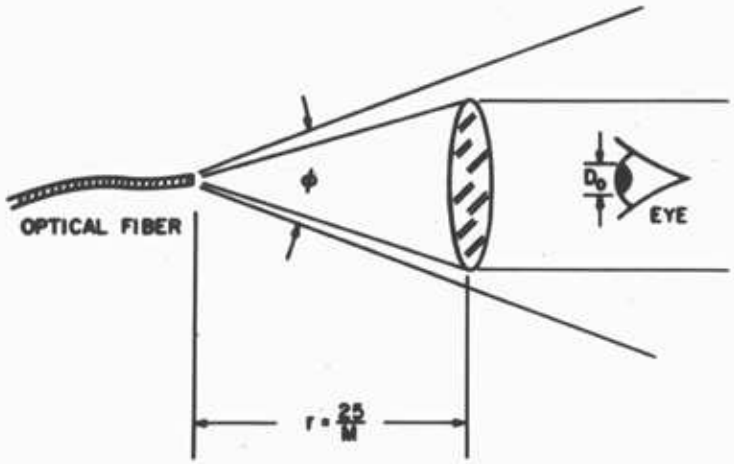
Few lasers actually emit a beam below the Class 1 limit (the AEL)

Diverging Beams

- Laser diode emitters and fiber-optic sources produce large beam spreads
- The risk is viewing these with an optical aid (jeweler's loupe or magnifier
- Often Class 1 or 1M



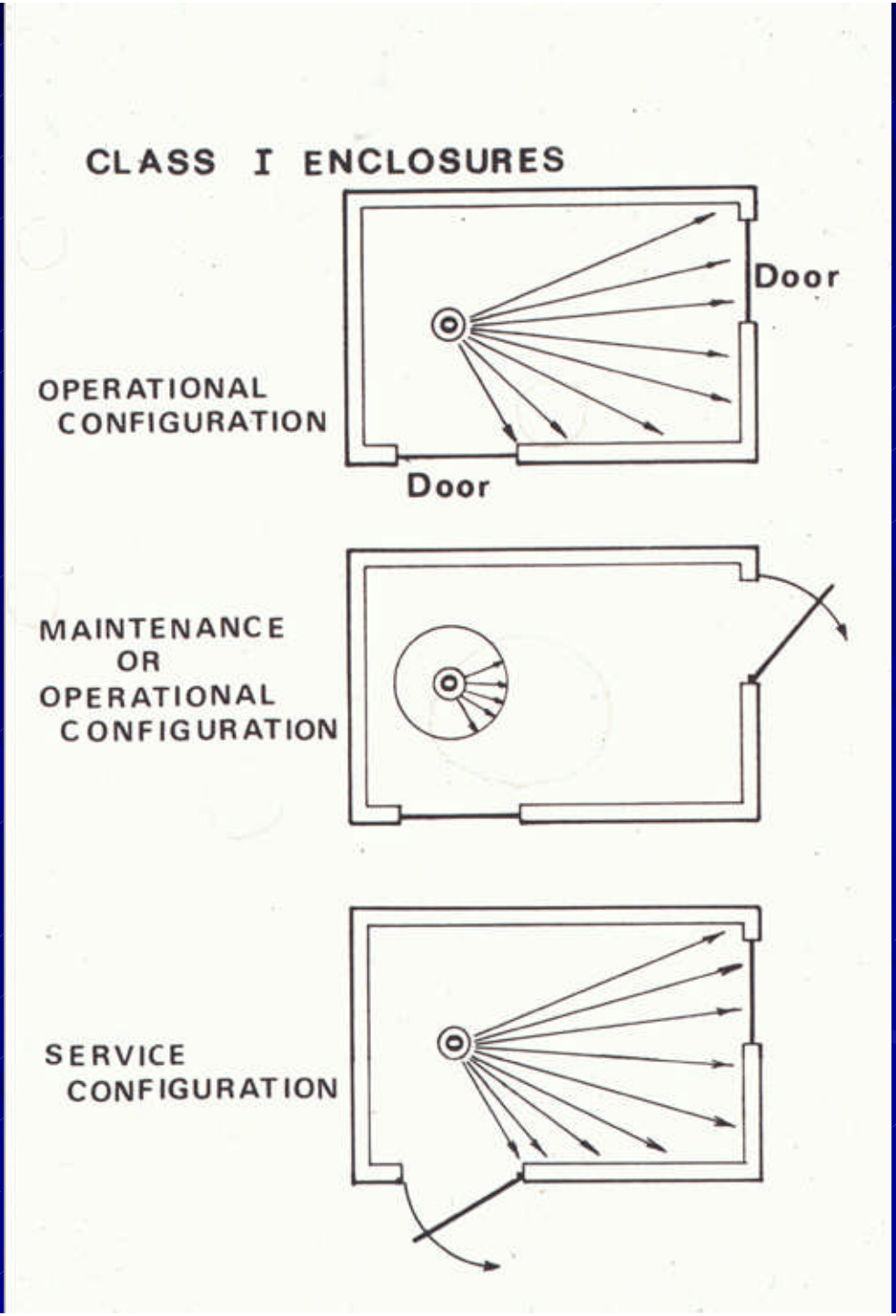
UNAIDED VIEWING

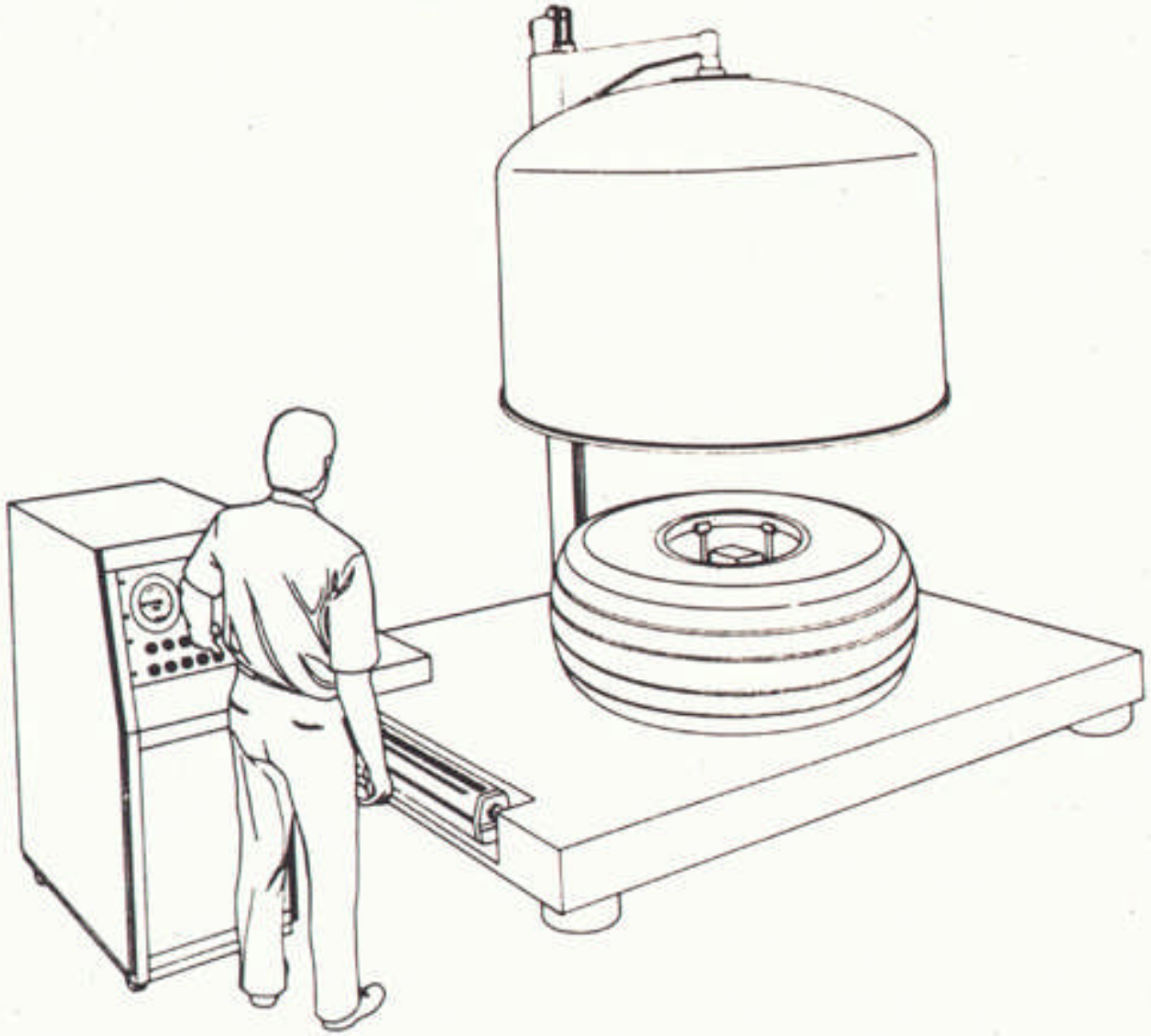


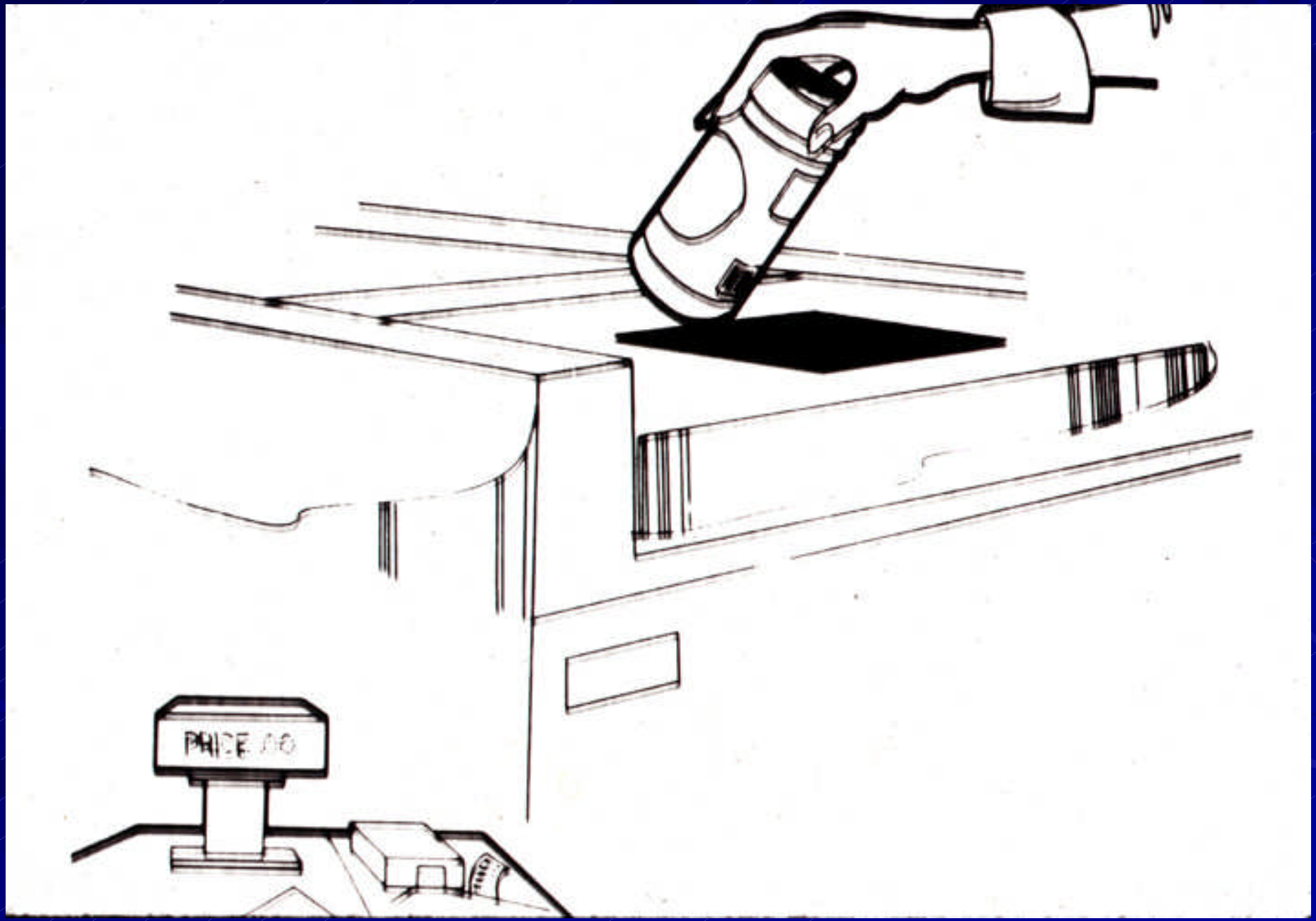
OPTICALLY AIDED VIEWING

Class 1

- Most laser products that are class 1 are Class 1 because of the enclosure
- The protective housing

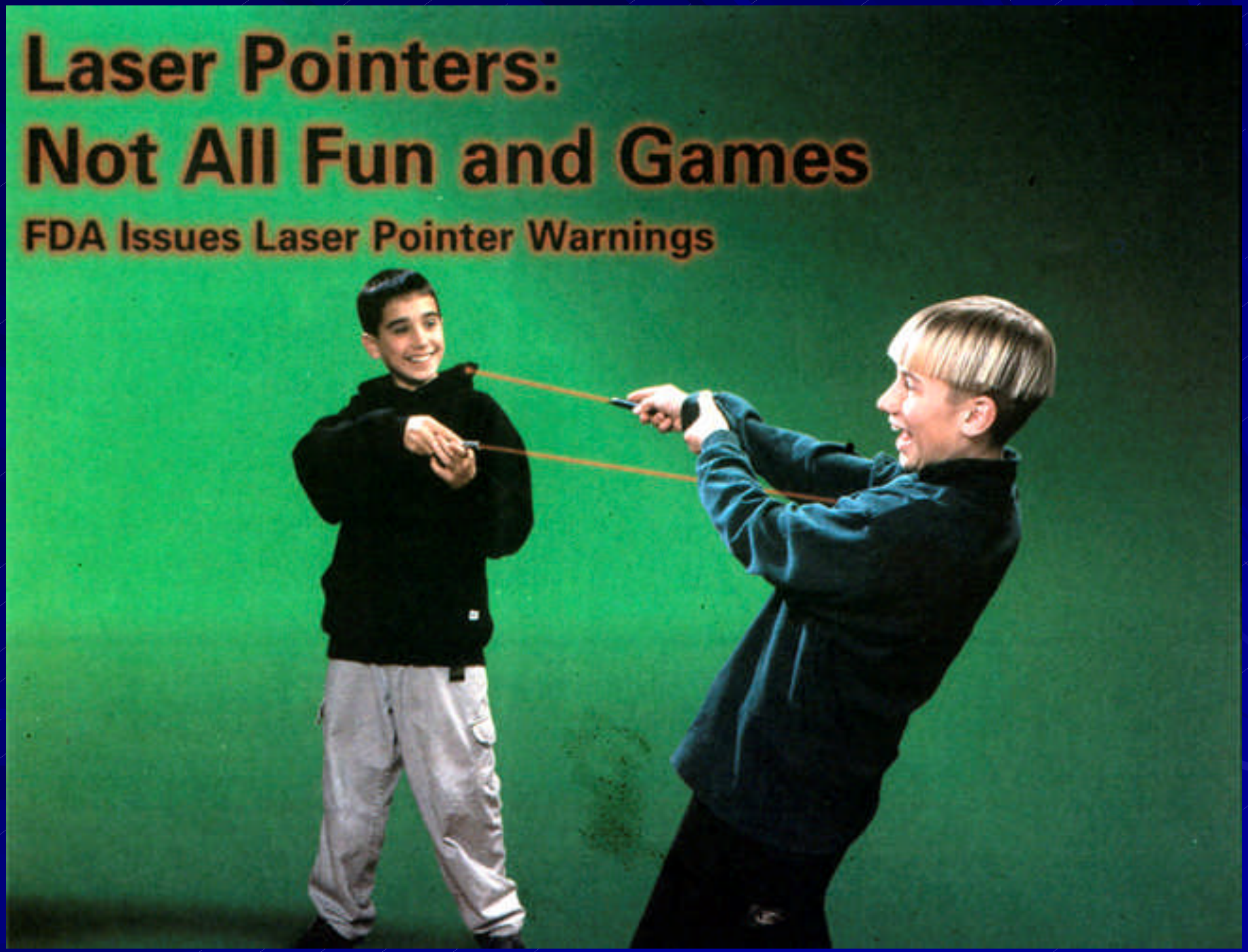





PRICE

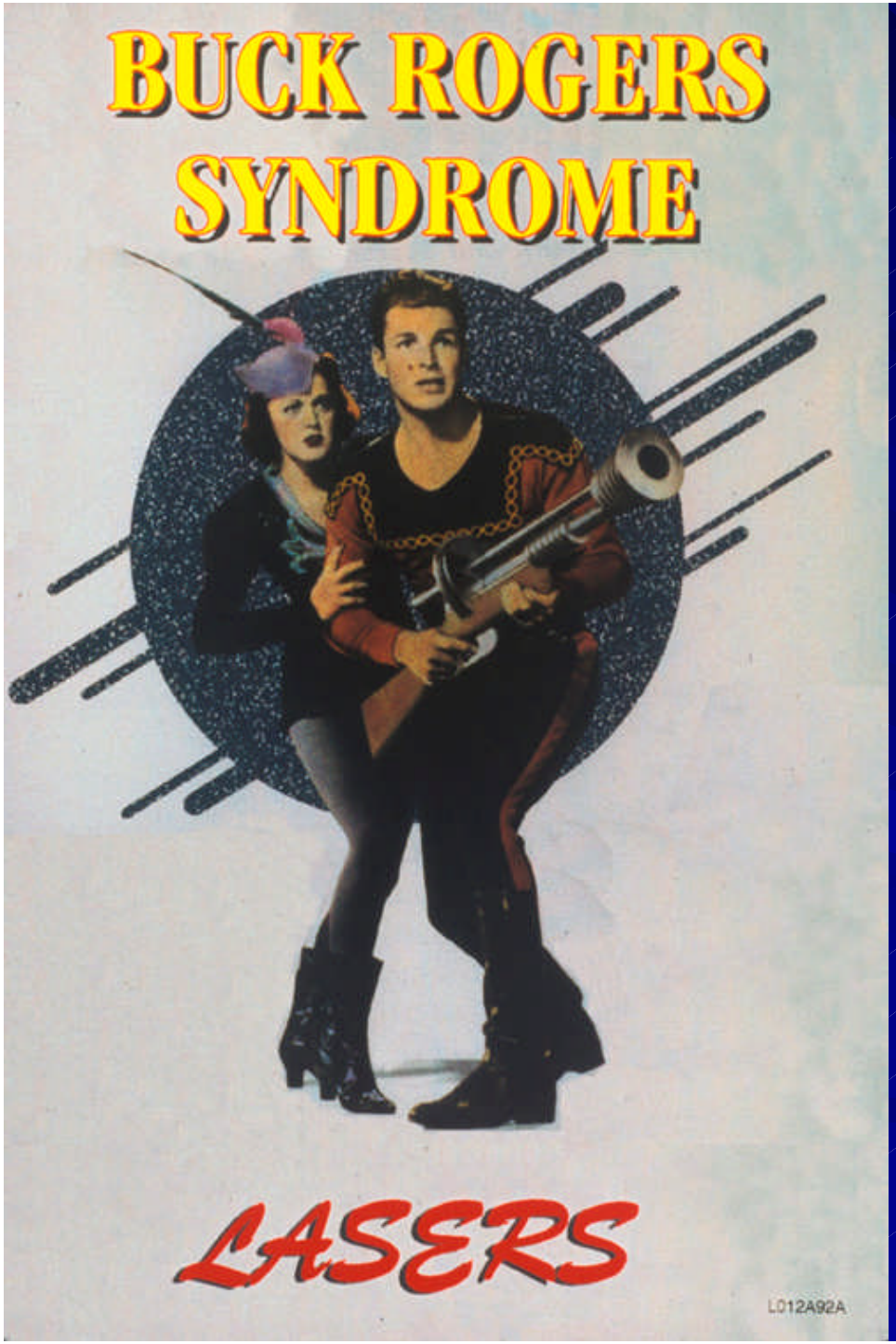
Laser Pointers: Not All Fun and Games

FDA Issues Laser Pointer Warnings



Class 3A (R)

- Most lasers used in alignment, leveling and construct work are Class 3A (new Class 3R)
- OSHA - Construction regulation



- *…Dealing with unwarranted*

  concerns

Relative Risks

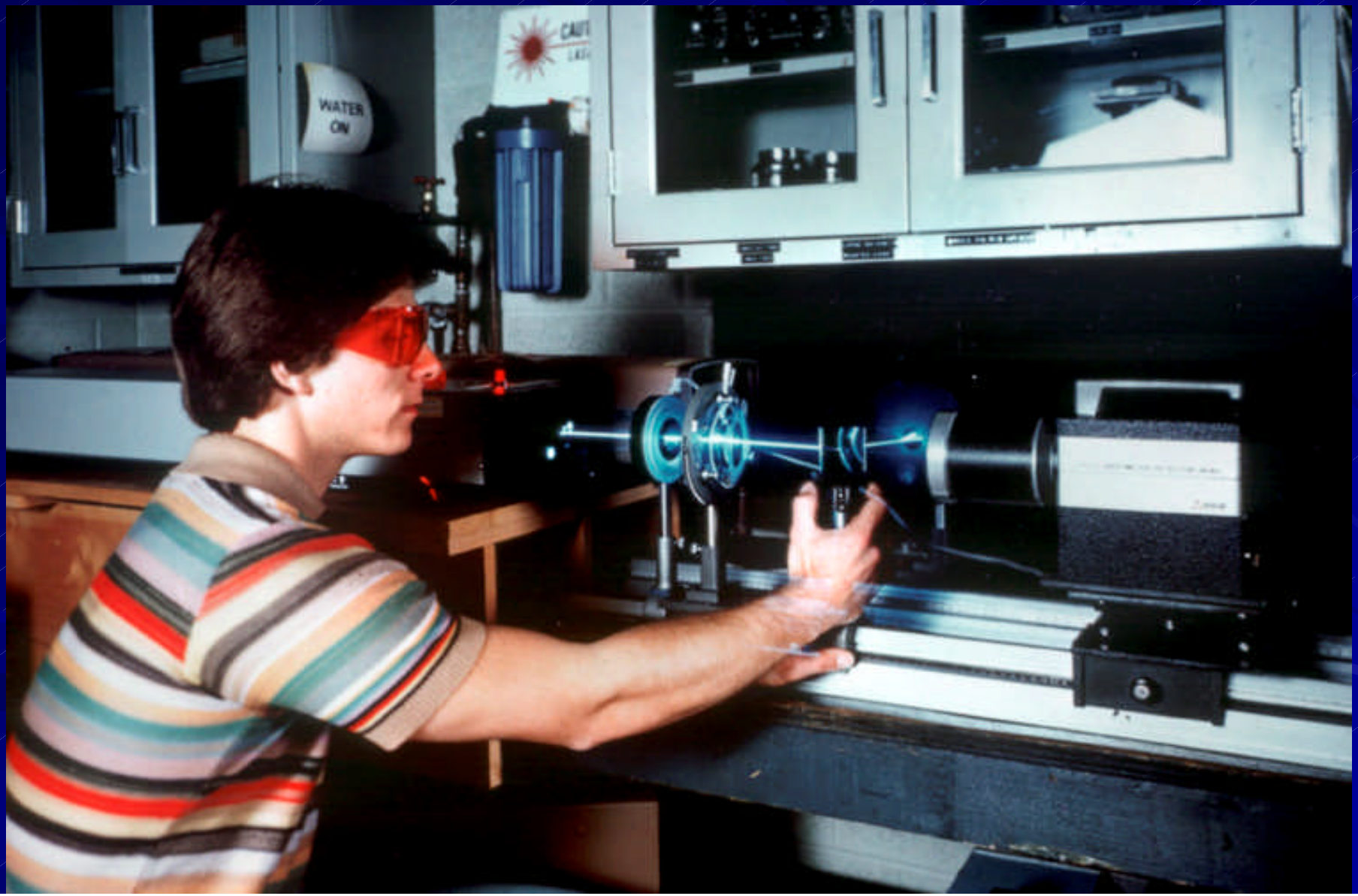
- Perceptions…

…Reality

- *A frequent problem in occupational health*

Classes 3b and Class 4

—the need for eyewear



On the Initial Laser Facility Audit Visit -- How Detailed?

- Determine the application and use environment for each laser
- Obtain all laser technical criteria
- You might consider obtaining a list of laser users, their training, (even eye exam history)
- You might even draw a simple diagram of the laser facility showing the beam path, equipment locations and doorways, etc.

On Initial Laser Facility Visits, consider…

- Perform a standard laser safety audit
- Perform an initial hazards analysis
- Properly document the initial visit and give copies to the laser users designating what items need correction and what actions are required
- Perform follow-up to assure compliance

In Performing Audits...consider taking with you:

- Audit/inspection form based on the ANSI Z136.1 or your program requirements
- A small inspection mirror for looking behind objects *(when laser is off!)*
- A small flashlight and magnifier to view labels
- A laser pointer to point out areas you may not want to physically touch
- Floor plans or diagrams of laser facilities

Other items to take along in performing an audit

- Laser signs and labels for on the spot correction of posting issues
- Laser Focus August 1977 Letter of David Decker addressed to laser users who do not wear protection
- Protective eyewear, clothing and beam finding tools (for use if laser is in operation)
- Maybe even a calibrated laser power meter

Auditing Laser Beam Hazards

- Determine locations of all exposed optics and the beam path
- It is usually safer and easier to perform inspection with the laser not energized
- Examine the walls in the beam plane for burn marks, and the ceiling as well
- Look behind beam stops to see if they are being left out of position
  - how are they secured?

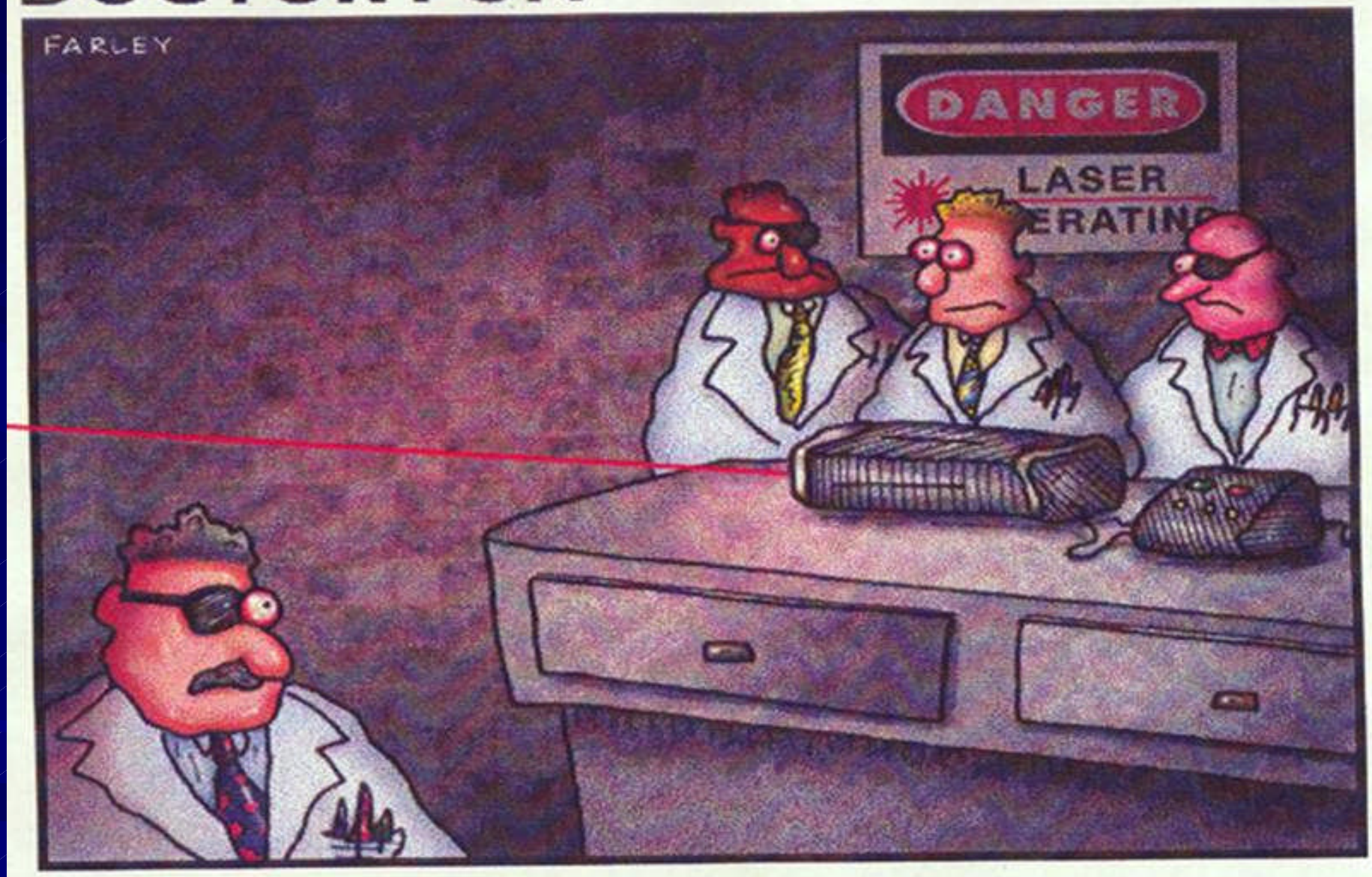
Auditing Laser Beam Hazards

- Determine if the beam is at eye level whether sitting or standing
- Determine if beam enclosures, beam tubes, fibers, collimators, etc. are in position
- Consider if the beam is being manipulated in some way which affects the hazard
- Examine environment for compatibility with the beam characteristics

…but when will they wear eye protection?

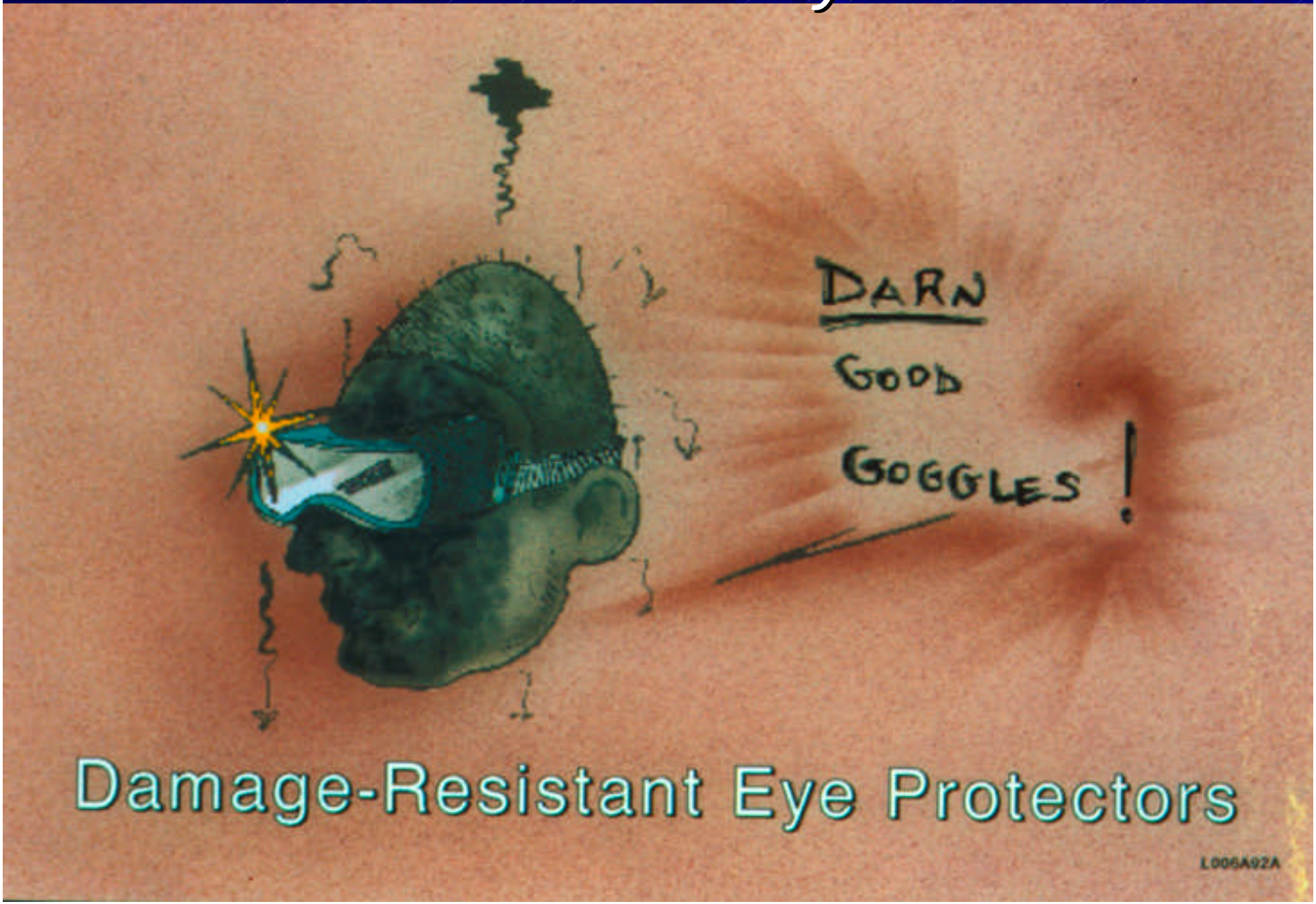
…when they are convinced there is a hazard!

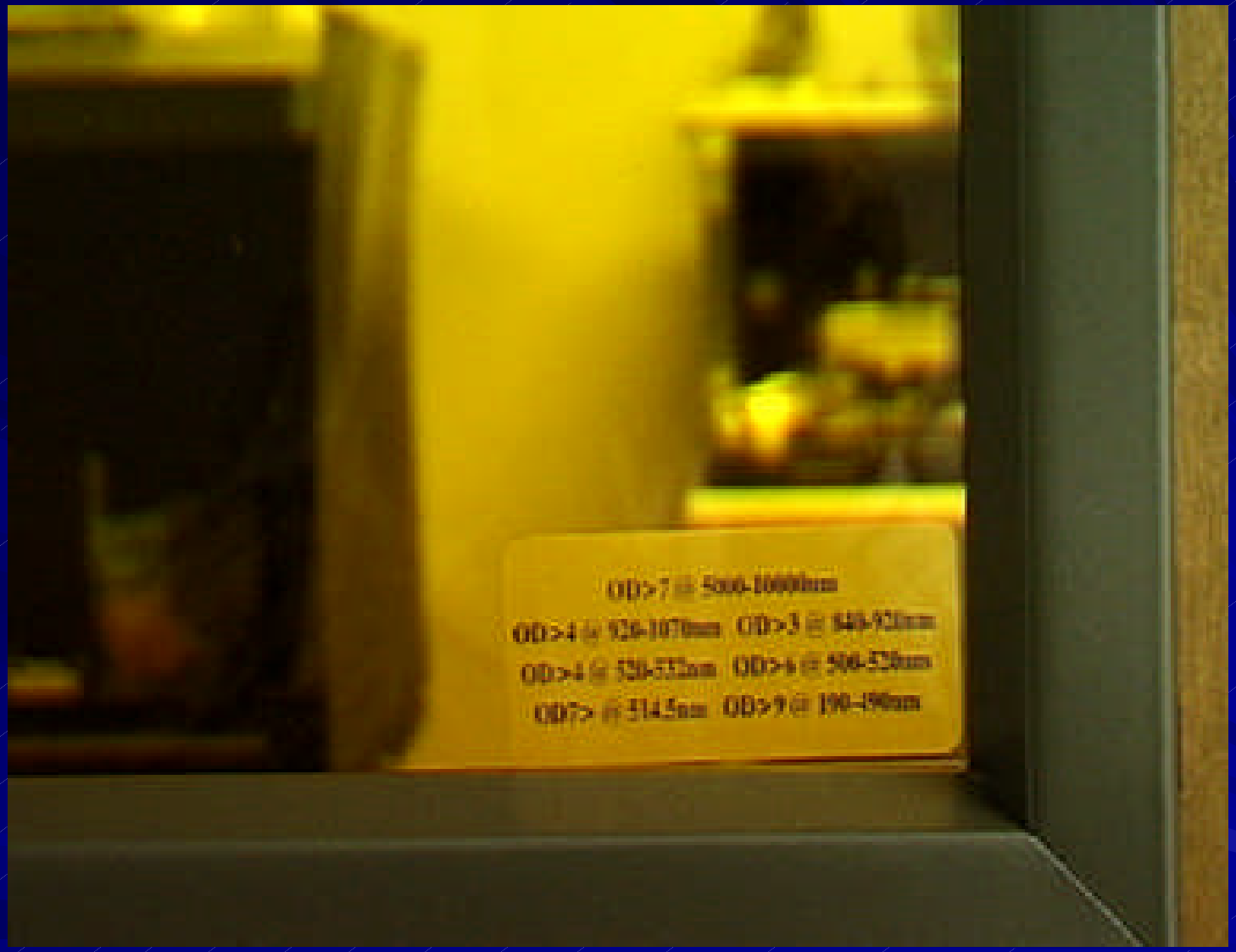
DOCTOR FUN



Peer pressure in the laser lab

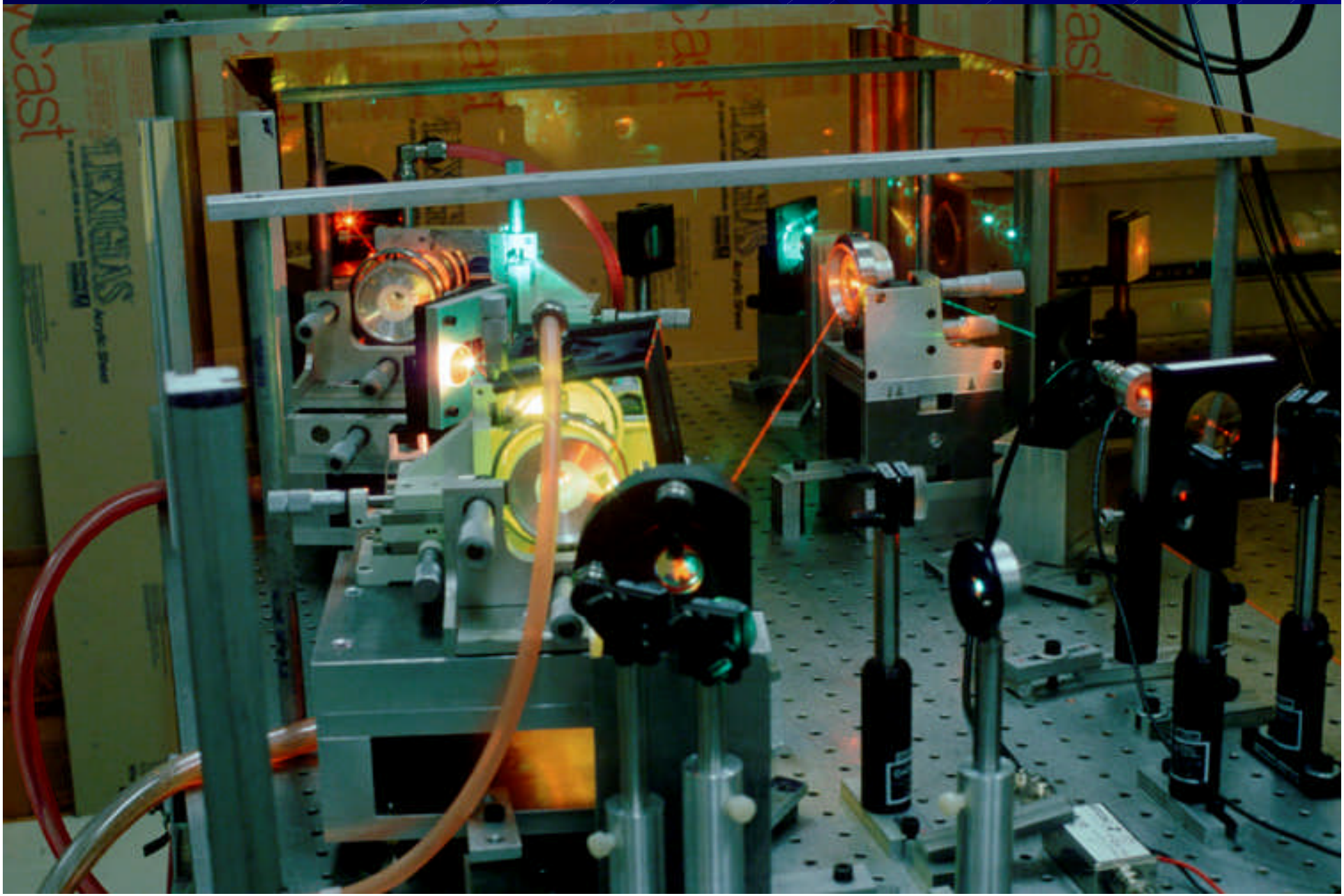
ANSI Z136.7—Laser Eye Protection





Informative Label on Windows

The problem of multiple beams of differing wavelengths

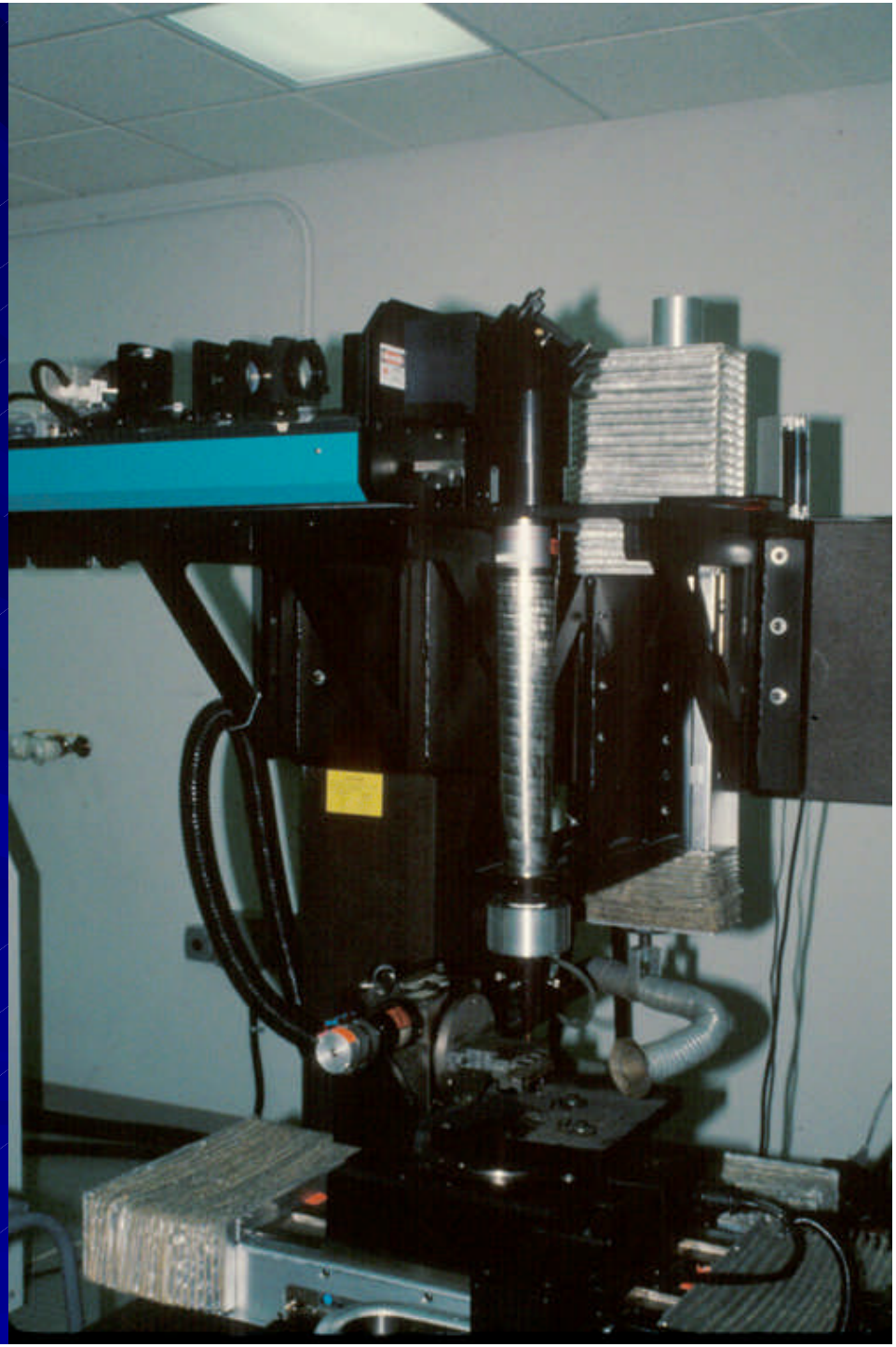


Auditing Laser Beam Hazards

- Check all interlocks, switches, and shutters to assure they are operating properly
- Examine laser safety eyewear to determine if it is appropriate
- Check postings, labeling, warning lights
- Examine SOPs for safety considerations
- Determine if training, eye exam requirements have been met
- Meet with laser user(s) to inform them of problems found and corrections needed before leaving the facility

Material Processing

- Class 4 levels are almost certainly required
- Multi-kilowatts
- Are there open-beams?
- Enclosures, ventilation?



Are you also auditing non-beam hazards? ANSI Z136.1-Section 7

- Look for obvious physical hazards
- Fire hazards, explosion hazards
- Are toxic laser media in use? Are proper control measures followed?
- Are laser-generated airborne contaminants (LGACs) being generated—and of concern
- Check for proper engineering controls (vent)
- Are optical tables grounded?

For example…

- Are compressed or cryogenic gases properly secured and used

- Appropriate controls

Documenting Audits

- Proper documentation is essential
- A formal check-off form may be useful
- Identify all items of non-compliance
- Notify laser user of non-compliance items
  - All required actions should be clearly identified and sent to the laser user(s)
- Assure all pertinent individuals are copied on audit reports
- Separate files—on each laser system or each laboratory or each laser user? Photos?

Audit Records and Program

- When do you need to follow-up and/or re-audit the laser facility?
- Would it be useful to draw a diagram of the laser facility?
- Would it be useful to take still pictures of the laser facilities? Add digital photos to report?
- Would it be useful to take a video of the laser facility?
- What QA procedures do you need for audit reports and/or your auditing program?

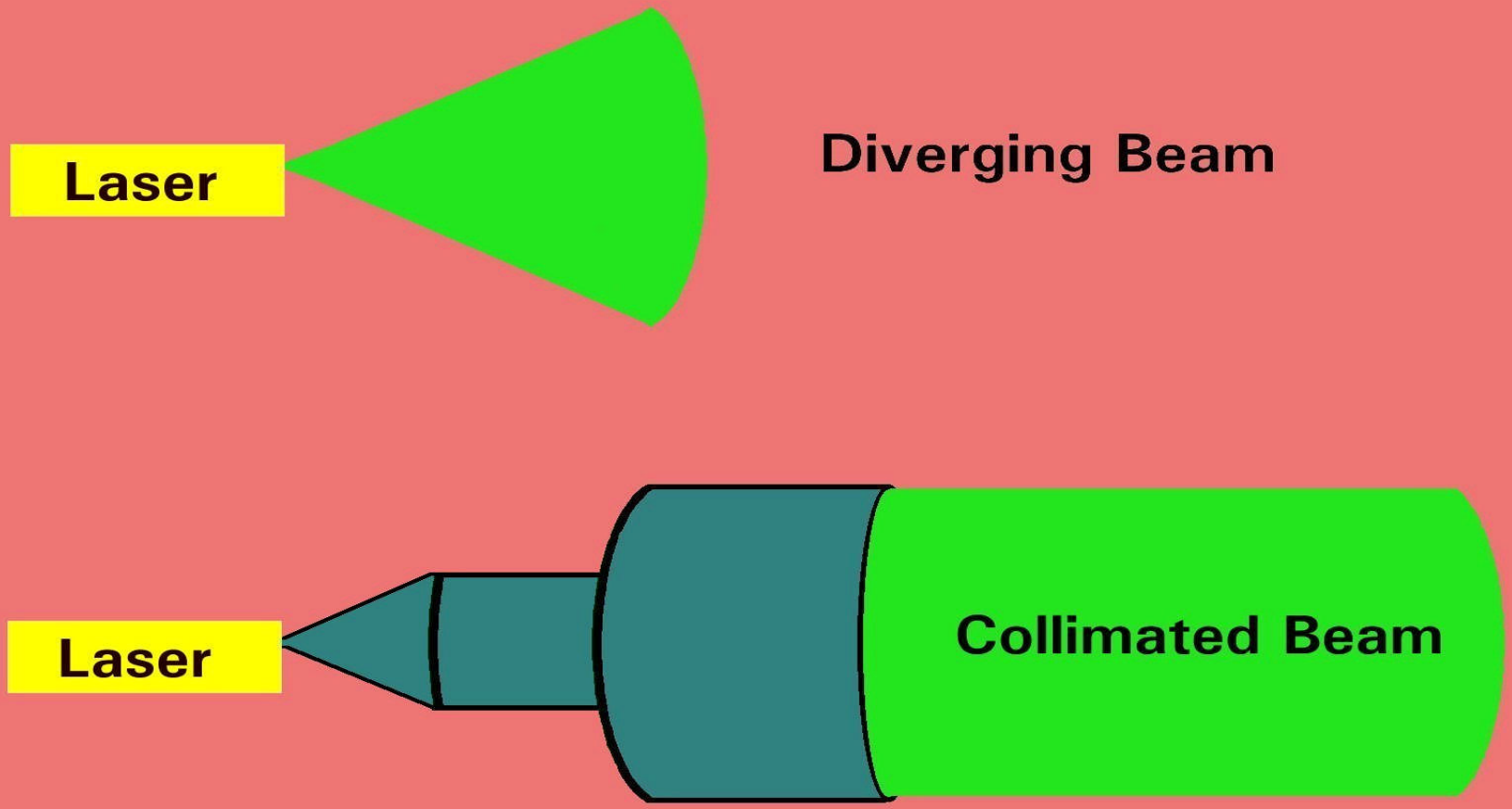
ANSI Z136 Activity—New Classes

- Hazard Evaluation Subcommittee added IEC changes in classification to Appendix H of ANSI Z136.1-2000
- Hazard Control Committee updated Section 4 in draft for the new revision
- New in ANSI—2006
- So what are these changes?

Revision of Classification Scheme in ANSI Z136.2-2006 edition

- All lasers of very low risk, “safe under reasonably foreseeable…: are Class 1 & 1M:
  - Class 1 eye safe even with optical aids
  - Class 1M eye safe except with optical aids
- All lasers of low risk due to aversion response are in Class 2 and 2M:
  - Class 2 safe for momentary viewing
  - Class 2M safe for momentary viewing w/o optical aids
- The transitional-zone Class 3A (US system) are now Class 3R -”Reduced Requirements”

Expanded or Expanding Beams



Optical Aids Can Collect This Energy

Impact of New Laser Safety Classification Scheme

- Despite the appearance of major changes, the actual impact on existing products will be minimal:
  - All current Class 1 are now Classes 1 and 1M.
  - Most current Class 2 are now Class 2 (or 2M if a highly diverging beam, e.g., a diode laser)
  - All current US Class 3A (IEC 3B*) “Danger” laser pointers are a new Class 3R
  - Class 3A expanded-beam lasers are rare outside military and are now in Class 1M or 2M

CDRH Laser Notice No. 50

- Issued on July 26, 2001
- Laser Products – Conformance with IEC 60825-1, Am.2 and 60601-2-22; Final Guidance for Industry and FDA
- You should now see some lasers with only the IEC marking that is obvious!

How Do I Recognize a Laser Product Certified to Meet the International Standard?

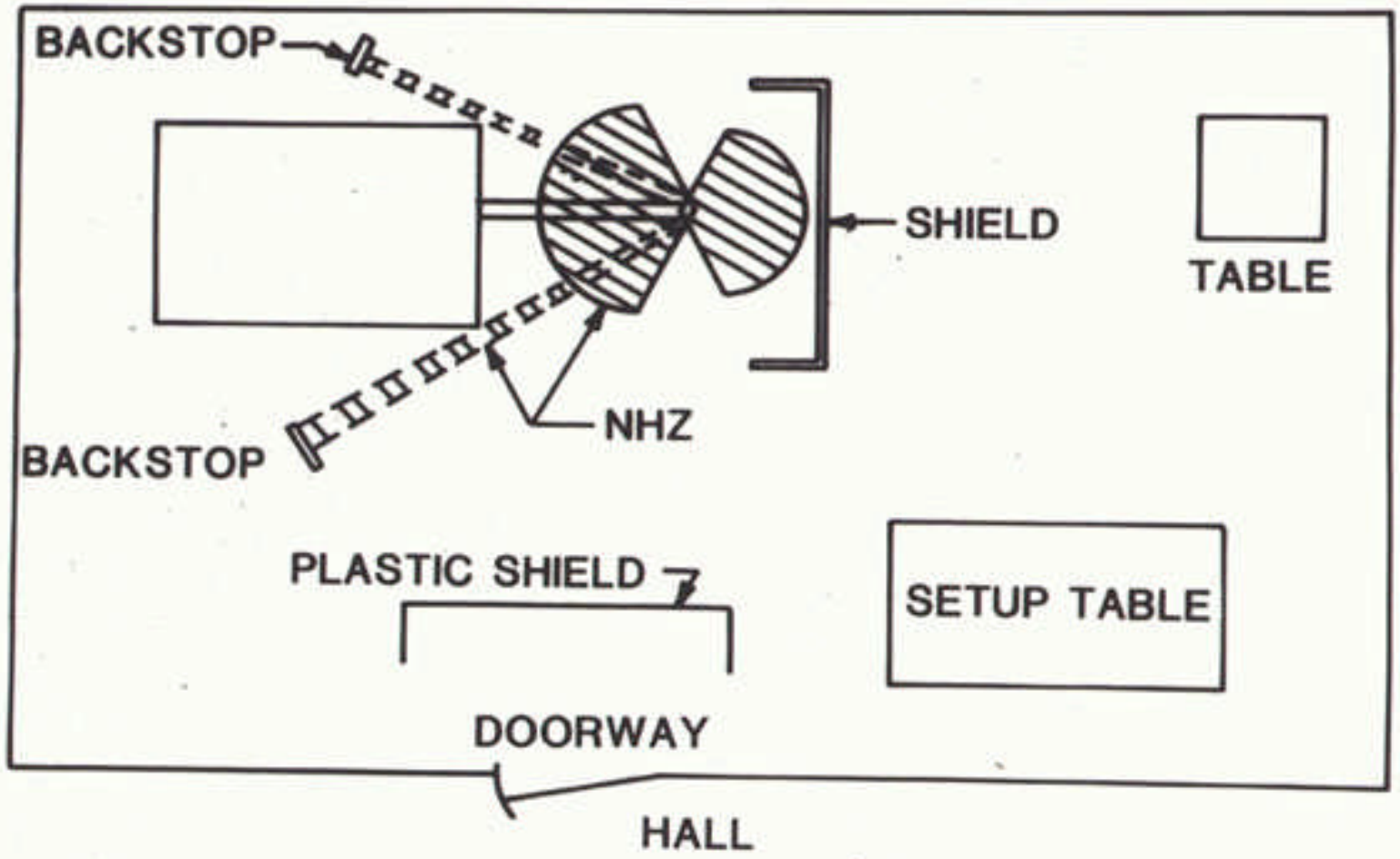
- Look for the certification label or explanatory label
- Use of new classifications such as 3R, 1M or 2M
- Appearance of the international laser safety logo (at right)

Hazard Evaluation

- Determine Laser Hazard Class(es)
- Determine beam paths
- Determine reflections
  - Specular reflections (collimated)
  - Specular reflections (curved)
  - Diffuse reflections
  - Retro-reflections

The Nominal Hazard Zone (NHZ)

- Range of hazardous reflections in most cases
- Range of hazardous, diverged, focused beam if not terminated
- Strict controls required within NHZ


BACKSTOP
SHIELD
TABLE
NHZ
BACKSTOP
PLASTIC SHIELD
SETUP TABLE
DOORWAY
HALL

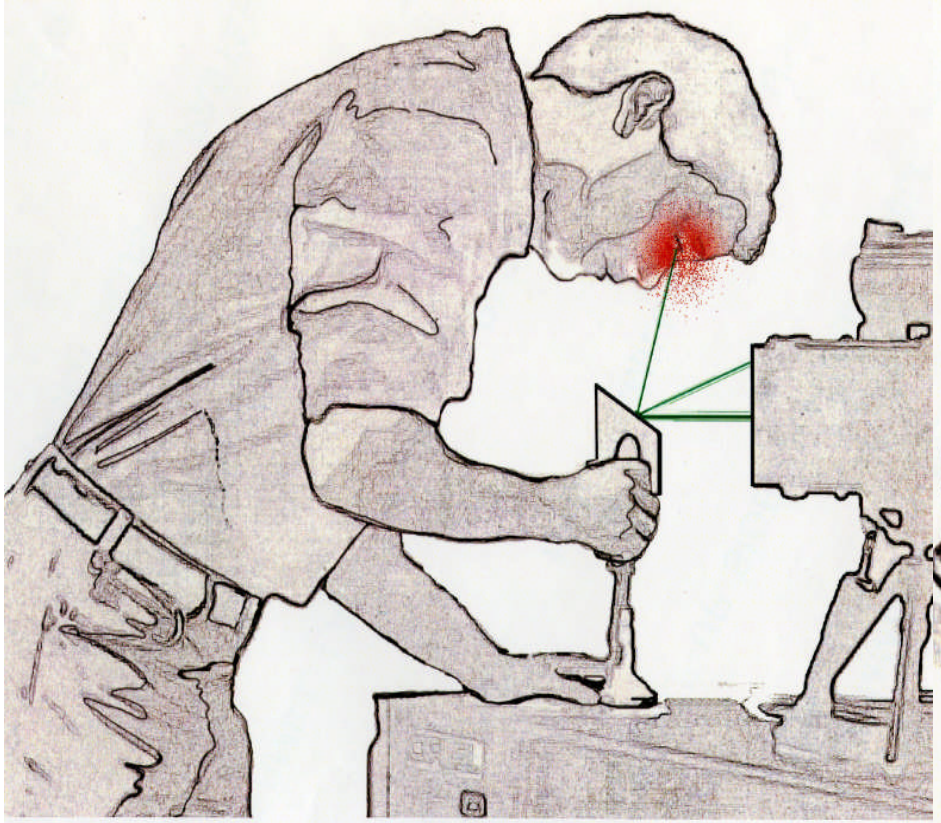
Risk of Exposure

- Compared to other laser work environments, open-beam laser operations is far more typical of research and development laboratories
- High risk of injury, but low probability of exposure
- Low chance of exposure leads to complacency.

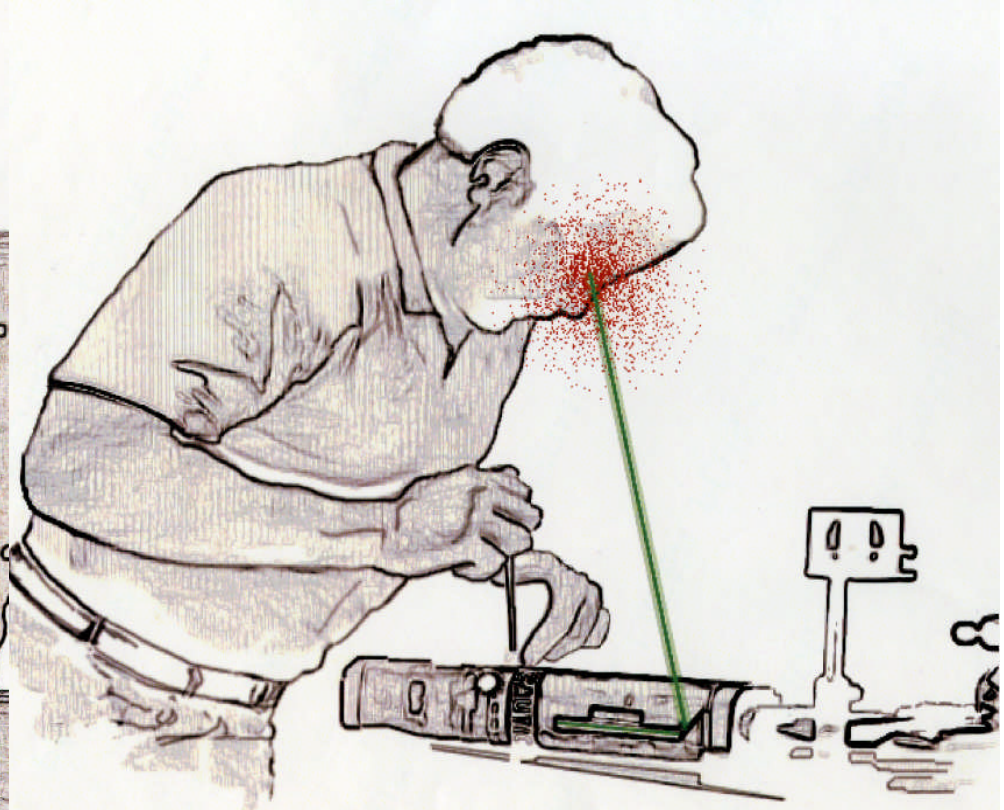
Goal: Control Secondary Beams

- Use enclosures where feasible
- Minimize the locations of open beams
- Provide flexible beam covers and beam tubes that are easy to move and install
- Terminate both the primary and secondary beams
- Wear laser eye protectors if beams are not enclosed

Many laboratory accidents result from unexpected upward reflections

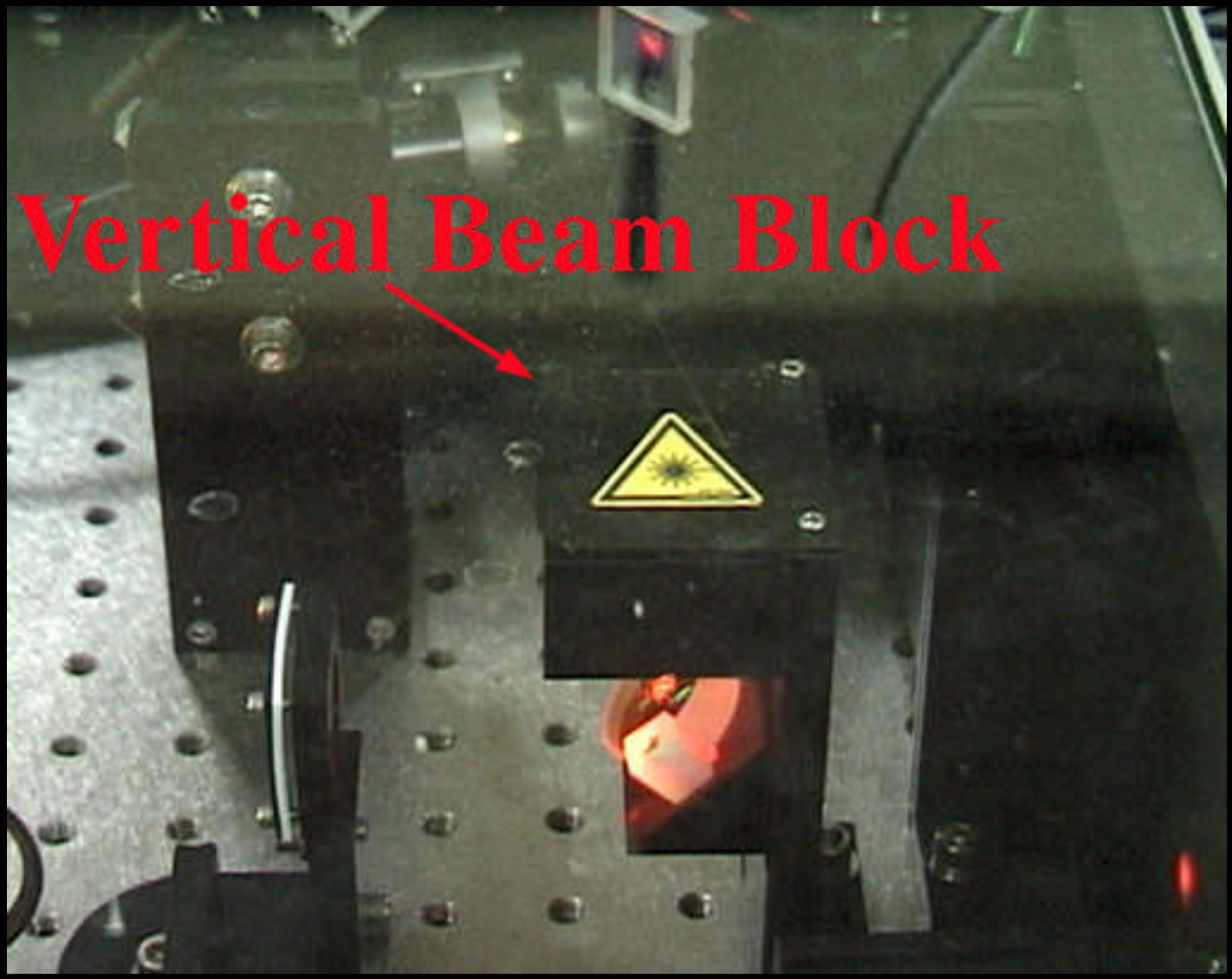


Turning Prism Secondary Reflection



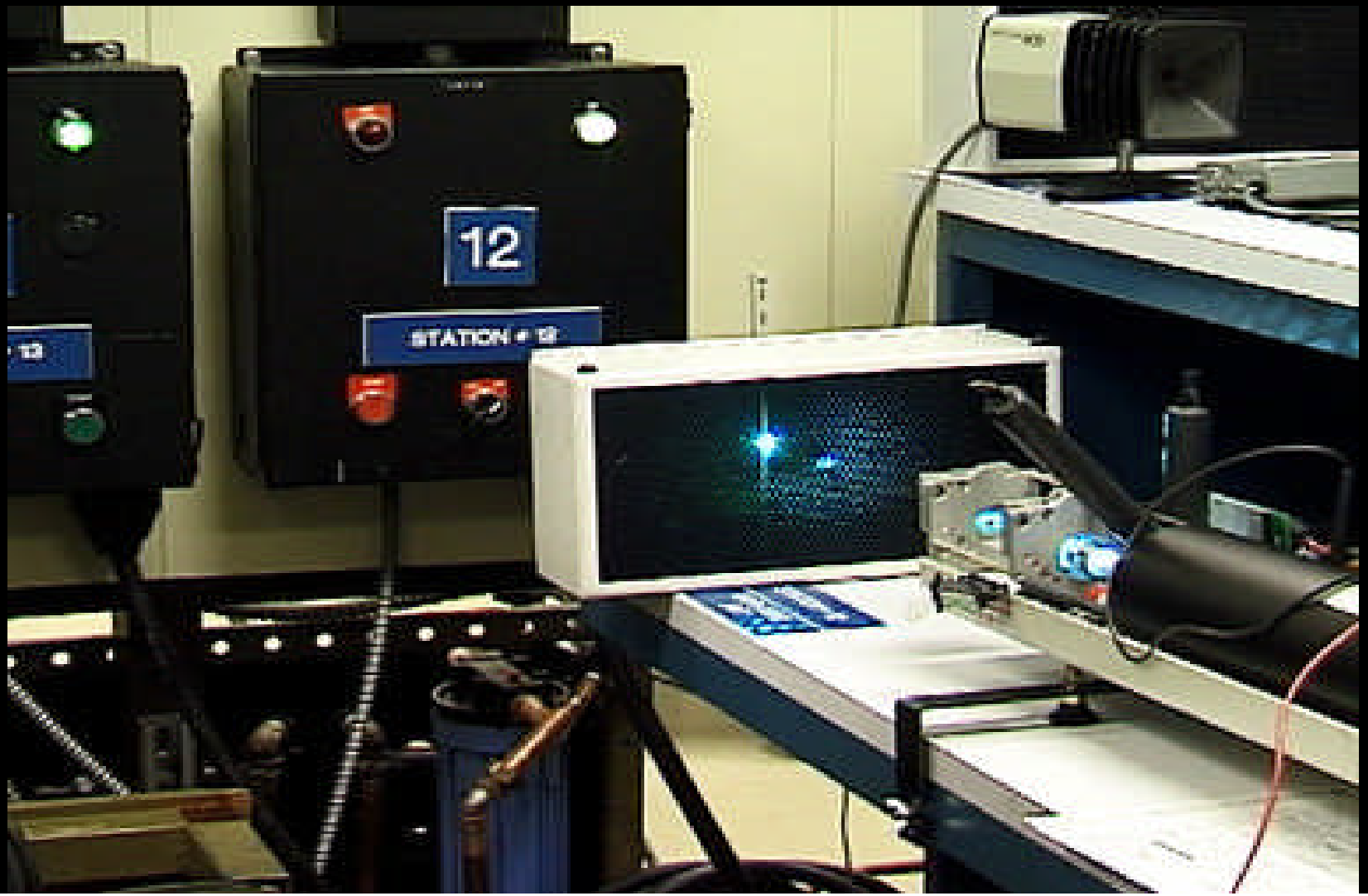
Brewster Window Reflection

D Sliney, in *Photonics Spectra*



Many ocular injuries in the laboratory result from upward beams

Backstops: Honeycomb

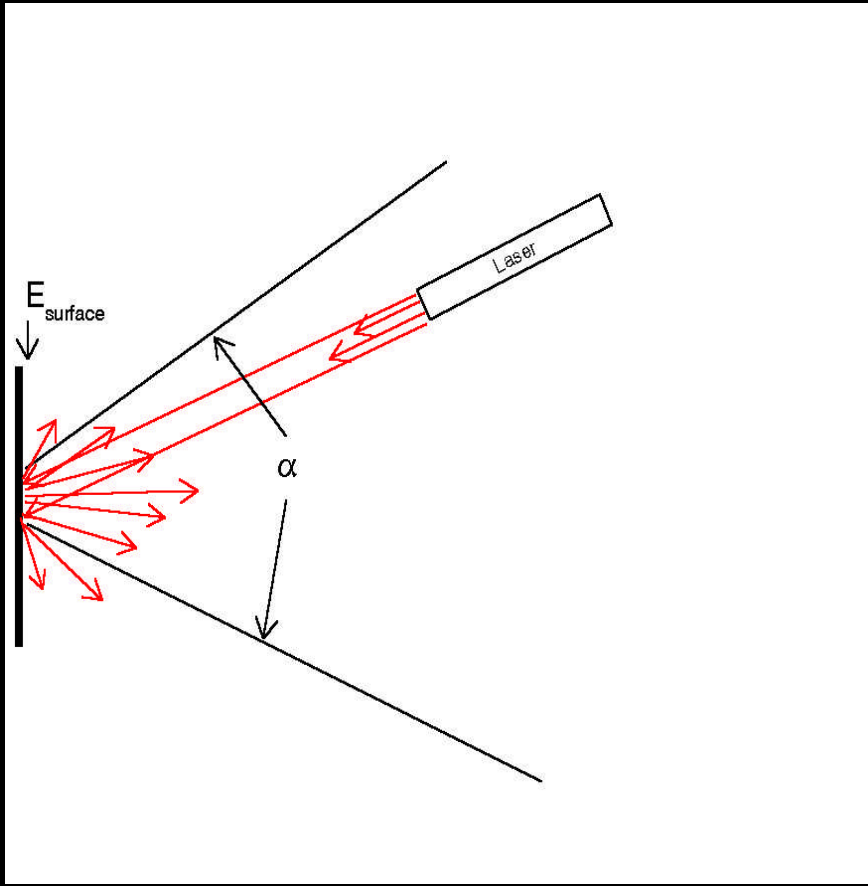


PROTECTION MEASURES

Engineering Controls	–	enclosures, interlocks, viewing panels, nonreflective surfaces.
Administrative Controls	–	restriction of access, warning signs, distance and time.
Personal Protection	–	eyewear, face masks, gloves and sleeves.

Diffuse reflections

- Potentially hazardous diffuse reflections are generally only possible and of concern with short-pulse, high-energy Class 4 laser operations
- Optical elements will produce some diffused radiant energy



“But I cannot see the beam if I wear laser eye protection!”

- What if you work with infrared lasers?
- You can’t see the beam there either
- Use viewing aids
  - Phosphor cards
  - Infrared imaging
  - Also works with visible
- Alignment goggles

Reduce the NHZ or wear eye protectors

- Add shielding around the beam path
- Enclose the entire beam path where feasible
- Wear laser safety eyewear if the beam is accessible
- Keep eyewear clean

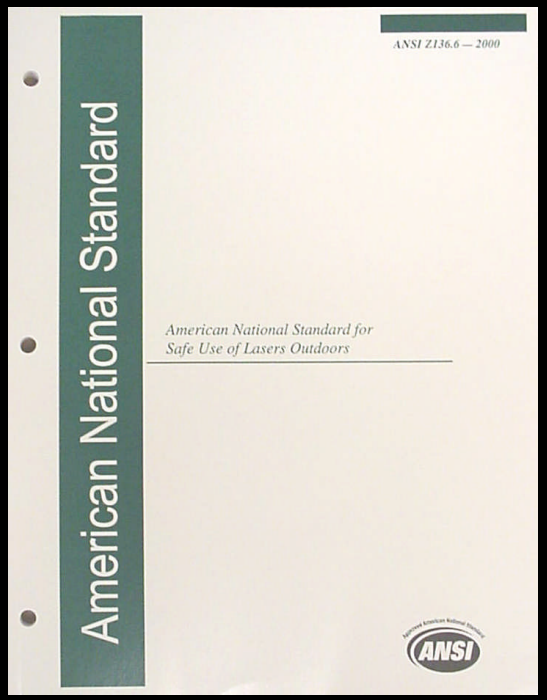
- Do visitors, students, summer-employees, post-docs have laser safety training?

Authorized Operators

Emergency Shut-Off (“Panic”) Switch

ANSI Z136.6-2000

American National Standard for the Safe Use of Lasers Outdoors



- Stimulated by incidents of pilot illuminations by laser light shows (from Casinos!)
- Introduces levels for transient visual effects
- Applies to outdoor scientific lasers
- Provides guidance for military use of lasers as well

ANSI Z136.6—Safe Use of Lasers Outdoors

Conclusions

- Lasers pose special problems where the beam is collimated and the hazard can exist at considerable distance
- Low probability of exposure, but severe eye injury could result
- Safety standards emphasize control measures that correspond to hazard classes
- Training is a key element of any laser safety program—an audit offers a great opportunity